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Technical Report
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Canada

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In conducting the research described in this report, the investigators adhered to the policies and procedures set out in the Tri-Council Policy Statement: Ethical conduct for research involving humans, National Council on Ethics in Human Research, Ottawa, 1998 as issued jointly by the Canadian Institutes of Health Research, the Natural Sciences and Engineering Research Council of Canada and the Social Sciences and Humanities Research Council of Canada.

Abstract

Background. Previous research conducted by DRDC Toronto to evaluate watch schedule variants used on RCN submarines indicated very significant and deleterious effects of the watch system on modeled cognitive effectiveness of RCN submariners. Subsequently, DRDC Toronto hosted an International Submarine Watch Schedule Symposium which led to a new RCN submarine watch schedule which improved modeled performance by about 30%. The RCN surface fleet is aware of this work and supported a request to conduct an evaluation of the surface fleet watch schedule. We evaluated the watch schedules used aboard HMCS St John's at the end of Op Nanook 2011, over the 8 days that STJ transitioned from the high Arctic to Halifax. **Methods.** The ages of the forty-five sailors who participated in this at-sea trial ranged from 21 to 48 years, with a mean age and standard deviation of 32.9 ± 7.7 years. Ten of these sailors were non-watch-standers, 14 sailors were from the 1-in-2 Port (Front) watch, 14 sailors were from the 1-in-2 Starboard (Back) watch, three sailors were from the 1-in-3 Engineering watch, and four sailors were from the 1-in-4 Engineering watch. All subjects wore wrist activity monitors (actigraphs) to measure their daily sleep patterns quantitatively. The actigraphically-measured sleep and daily work hours were the two data sets that were inputted to the FAST™ (Fatigue Avoidance Scheduling Tool) software to generate modeled cognitive effectiveness for each subject. All subjects maintained a daily activity, sleep and mood log. **Results.** Modeled cognitive effectiveness showed worrisome levels of performance equivalent to intoxicated levels of blood alcohol (BAC 0.05% and 0.08%) and well beyond those levels for all watch system variants. The main effect of 'groups' for 'difficulty falling asleep' was significant with post hoc tests showing that the 1-in-2 Port (Front) watch had less difficulty getting to sleep relative to the non-watch standers. With respect to the Visual Analogue Scale data, the non-watch-standers reported being in a 'happier' mood than either of the 1-in-2 Port (Front) and Starboard (Back) watch. Collapsed over the non-watch-standers, 1-in-2 Port (Front) watch, and 1-in-2 Starboard (Back) watch syndicates, 6 SOAP parameters (difficulty concentrating, level of depression, level of irritability, level of fatigue, work frustration and physical discomfort) deteriorated during the trial relative to the pre-trial baseline. **Conclusions.** The current surface fleet watch schedule is sub-optimal in that it results in worrisome levels of cognitive effectiveness in many of our sailors. **Recommendations.** An alternative watch schedule which is more sparing of submariner cognitive effectiveness should be developed and implemented. Please see the details of an alternative watch system in the body of this report under 'recommendations'.

Résumé

Contexte. Des recherches antérieures réalisées par RDDC Toronto pour évaluer les variantes d'horaire de garde utilisées à bord des sous-marins de la MRC montrent des incidences importantes et néfastes du système de quart sur l'efficacité cognitive des sous-mariniers. Subséquemment, RDDC Toronto a organisé un symposium international sur les horaires de garde à bord des sous-marins qui a permis de réaliser un nouvel horaire de garde à bord des sous-marins de la MRC, améliorant d'environ 30 p. cent le rendement modélisé. Les membres de la flotte de surface de la MRC connaissent ces travaux et ont demandé qu'une évaluation de l'horaire de garde de la flotte de surface soit réalisée. Nous avons évalué les horaires de garde utilisés à bord du NCSM *St John's* à la fin de l'opération *Nanook* 2011, pendant les huit jours de la traversée du *St John's* de l'Extrême-Arctique à Halifax. **Méthodologie.** Les quarante-cinq marins qui ont participé à cette expérience en mer étaient âgées de 21 à 48 ans, avec une moyenne d'âge de 32,9 ans et un écart type de ± 7,7 ans. Dix de ces marins étaient affectés à des postes autres que des poste de garde, quatorze étaient affectés comme vigies de quart avant, à raison d'un tour de garde sur deux, quatorze comme vigies de quart arrière, à raison d'un tour de garde sur deux, trois comme mécaniciens chefs de quart, à raison d'un tour de garde sur trois et quatre comme mécaniciens chefs de quart, à raison d'un tour de garde sur quatre. Chacun des participants portait un bracelet moniteur (actigraphe) de ses activités, afin de mesurer quantitativement sa structure de sommeil. Les heures de travail quotidien et de sommeil mesurées par actigraphe sont les deux ensembles de données enregistrés dans le logiciel FAST^{TM} (*Fatigue Avoidance Scheduling Tool*) pour établir l'efficacité cognitive de chaque participant. Tous les participants ont tenu, quotidiennement, un registre sur leurs activités, leur sommeil et leur humeur. **Résultats.** L'efficacité cognitive a montré des niveaux de rendement inquiétants, équivalents à un rendement en état d'ébriété (à un taux d'alcoolémie se situant entre 0,05 % et 0,08 %) et bien au-delà des niveaux de toutes les variantes d'un système de garde. Le principal effet des « groupes » à l'égard de la « difficulté à s'endormir » s'est avéré important dans les essais ultérieurs montrant que les vigies de quart avant, à raison d'un tour sur deux, avaient moins de difficulté à s'endormir que les marins affectés à des postes autres que des poste de garde. En ce qui concerne les données de l'échelle visuelle analogue, les marins affectés à des postes autres que des poste de garde se sont avérés être de meilleure humeur que les vigies de quart avant et les vigies de quart arrière, à raison d'un tour de garde sur deux. Tant chez les marins affectés à des postes autres que des poste de garde, que chez les vigies de quart avant et les vigies de quart arrière, à raison d'un tour de garde sur deux, six paramètres du profil d'évaluation des opérations spéciales (difficulté de concentration, niveau de dépression, niveau d'irritabilité, niveau de fatigue, frustration au travail et inconfort physique) se sont détériorés au cours de l'essai. **Conclusions.** L'horaire de garde actuel de la flotte de surface est sous-optimal du fait qu'il entraîne une réduction inquiétante du niveau d'efficacité cognitive de certains de nos marins. **Recommandations.** Un nouvel horaire de garde, moins éprouvant pour l'efficacité cognitive des sous-mariniers, devrait être élaboré et mis en œuvre. Veuillez voir les détails d'un nouvel horaire de garde dans le corps du présent rapport sous « Recommandations ».

Executive summary

An assessment of some watch schedule variants used in Cdn Patrol Frigates: OP Nanook 2011

Michel A. Paul; Daniel Ebisuzaki; Jason McHarg; Steven R. Hursh; James C. Miller; DRDC Toronto TR 2012-078; Defence R&D Canada – Toronto; December 2012.

Background. Previous research conducted by DRDC Toronto to evaluate watch schedule variants used on RCN submarines indicated very significant and deleterious effects of the watch system on modeled cognitive effectiveness of RCN submariners. Subsequently, DRDC Toronto hosted an International Submarine Watch Schedule Symposium which led to a new RCN submarine watch schedule which improved modeled performance by about 30%. The RCN surface fleet is aware of this work and supported a request to conduct an evaluation of the surface fleet watch schedule. We evaluated the watch schedules used aboard HMCS St John's at the end of Op Nanook 2011, over the 8 days that STJ transitioned from the high Arctic to Halifax. **Methods.** The ages of the forty-five sailors who participated in this at-sea trial ranged from 21 to 48 years, with a mean age and standard deviation of 32.9 ± 7.7 years. Ten of these sailors were non-watch-standers, 14 sailors were from the 1-in-2 Port (Front) watch, 14 sailors were from the 1-in-2 Starboard (Back) watch, three sailors were from the 1-in-3 Engineering watch, and four sailors were from the 1-in-4 Engineering watch. All subjects wore wrist activity monitors (actigraphs) to measure their daily sleep patterns quantitatively. The actigraphically-measured sleep and daily work hours were the two data sets that were inputted to the FAST™ (Fatigue Avoidance Scheduling Tool) software to generate modeled cognitive effectiveness for each subject. All subjects maintained a daily activity, sleep and mood log. **Results.** Modeled cognitive effectiveness showed worrisome levels of performance equivalent to intoxicated levels of blood alcohol (BAC 0.05% and 0.08%) and well beyond those levels for all watch system variants, with the worst results in the 1-in-2 Starboard (Back) watch. The main effect of 'groups' for 'difficulty falling asleep' was significant with post hoc tests showing that the 1-in-2 Port (Front) watch had less difficulty getting to sleep relative to the non-watch standers. With respect to the Visual Analogue Scale data, the non-watch-standers reported being in a 'happier' mood than either of the 1-in-2 Port (Front) and Starboard (Back) watch. Collapsed over the non-watch-standers, 1-in-2 Port (Front) watch, and 1-in-2 Starboard (Back) watch syndicates, 6 Special Operations Assessment Profile (SOAP) parameters (difficulty concentrating, level of depression, level of irritability, level of fatigue, work frustration and physical discomfort) deteriorated during the trial relative to the pre-trial baseline. **Conclusions.** The current surface fleet watch schedule is sub-optimal in that it results in worrisome levels of cognitive effectiveness in some of our sailors. **Recommendations.** An alternative watch schedule which is more sparing of submariner cognitive effectiveness should be developed and implemented. In the event that the RCN cannot support a straight 8s 1-in-3 system (which is the best possible watch system) to replace the current 1-in-2 watch system (7-on, 7-off, 5-on, 5-off), an the 8-on, 8-off, 4-on, 4-off system would be a significant improvement over the current system. One of the features of this 8-on, 8-off, 4-on-4-off system would be a watch change at 0400 h thus splitting the very fatiguing night work equally between front and back watches). While not optimal, it would be a significant improvement over the current 7-on, 7-off, 5-on 5-off 1-in-2 watch system.

Sommaire

An assessment of some watch schedule variants used in Cdn Patrol Frigates: OP Nanook 2011

Michel A. Paul; Daniel Ebisuzaki; Jason McHarg; Steven R. Hursh; James C. Miller ; DRDC Toronto TR 2012-078 ; R & D pour la défense Canada – Toronto; décembre 2012.

Contexte. Des recherches antérieures réalisées par RDDC Toronto pour évaluer les variantes d'horaire de garde utilisées à bord des sous-marins de la MRC montrent des incidences importantes et néfastes du système de quart sur l'efficacité cognitive des sous-mariniers. Subséquemment, RDDC Toronto a organisé un symposium international sur les horaires de garde à bord des sous-marins qui a permis de réaliser un nouvel horaire de garde à bord des sous-marins de la MRC, améliorant d'environ 30 p. cent le rendement modélisé. Les membres de la flotte de surface de la MRC connaissent ces travaux et ont demandé qu'une évaluation de l'horaire de garde de la flotte de surface soit réalisée. Nous avons évalué les horaires de garde utilisés à bord du NCSM *St John's* à la fin de l'opération *Nanook* 2011, pendant les huit jours de la traversée du *St John's* de l'Extrême-Arctique à Halifax.

Méthodologie. Les quarante-cinq marins qui ont participé à cette expérience en mer étaient âgées de 21 à 48 ans, avec une moyenne d'âge de 32,9 ans et un écart type de ± 7,7 ans. Dix de ces marins étaient affectés à des postes autres que des poste de garde, quatorze étaient affectés comme vigies de quart avant, à raison d'un tour de garde sur deux, quatorze comme vigies de quart arrière, à raison d'un tour de garde sur deux, trois comme mécaniciens chefs de quart, à raison d'un tour de garde sur trois et quatre comme mécaniciens chefs de quart, à raison d'un tour de garde sur quatre. Chacun des participants portait un bracelet moniteur (actigraphe) de ses activités, afin de mesurer quantitativement sa structure de sommeil. Les heures de travail quotidien et de sommeil mesurées par actigraphe sont les deux ensembles de données enregistrés dans le logiciel FAST^{TM} (*Fatigue Avoidance Scheduling Tool*) pour établir l'efficacité cognitive de chaque participant. Tous les participants ont tenu, quotidiennement, un registre sur leurs activités, leur sommeil et leur humeur.

Résultats. L'efficacité cognitive a montré des niveaux de rendement inquiétants, équivalents à un rendement en état d'ébriété (à un taux d'alcoolémie se situant entre 0,05 % et 0,08 %) et bien au-delà des niveaux de toutes les variantes d'un système de garde, le pire résultat étant celui de la vigie de quart arrière, à raison d'un tour de garde sur deux. Le principal effet des « groupes » à l'égard de la « difficulté à s'endormir » s'est avéré important dans les essais ultérieurs montrant que les vigies de quart avant, à raison d'un tour sur deux, avaient moins de difficulté à s'endormir que les marins affectés à des postes autres que des poste de garde. En ce qui concerne les données de l'échelle visuelle analogue, les marins affectés à des postes autres que des poste de garde se sont avérés être de meilleure humeur que les vigies de quart avant et les vigies de quart arrière, à raison d'un tour de garde sur deux. Tant chez les marins affectés à des postes autres que des poste de garde, que chez les vigies de quart avant et les vigies de quart arrière, à raison d'un tour de garde sur deux, six paramètres du profil d'évaluation des opérations spéciales (difficulté de concentration, niveau de dépression, niveau d'irritabilité, niveau de fatigue, frustration au travail et inconfort physique) se sont détériorés au cours de l'essai.

Conclusions. L'horaire de garde actuel de la flotte de surface est sous-optimal du fait qu'il entraîne une réduction inquiétante du niveau d'efficacité cognitive de certains de nos marins.

Recommandations. Un nouvel horaire de garde, moins éprouvant pour l'efficacité cognitive des sous-mariniers, devrait être élaboré et mis en œuvre. Si la MRC ne peut utiliser un horaire d'un tour sur trois de huit heures (le meilleur horaire de garde qui soit) pour remplacer l'horaire actuel d'un tour sur deux (7-7-5-5), un horaire 8-8-4-4 constituerait une amélioration importante par rapport au système actuel. Une des caractéristiques de cet horaire 8-8-4-4 serait un changement de garde à 4 h, ce qui permettrait de répartir également le travail de nuit exténuant entre les vigies de quart avant et arrière. Bien qu'il ne soit pas optimal, il constituerait une amélioration importante par rapport au système de garde actuel 7-7-5-5, à raison d'un tour sur deux.

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1 Background

In October 2005 we (DRDC Toronto) we were asked to support the Board of Inquiry (BOI) investigating the fire on HMCS Chicoutimi. We provided the BOI with FAST^{TM} (Fatigue Avoidance Scheduling Tool) models based on sleep behaviour estimates to provide estimates of modeled cognitive effectiveness of the crew at the time of the fire and 28 hours after the fire when the casualty was evacuated from the boat by Helicopter. The inputs to FAST^{TM} are two streams of data; actigraphically-measured daily sleep and daily duty hours. The output of FAST ^{TM} is modeled cognitive effectiveness. These FAST models suggested that the watch schedule in use on CF submarines at the time resulted in very significant decreases in modeled submariner cognitive effectiveness. Therefore, the CF Submarine community tasked DRDC Toronto to conduct a trial on HMCS Corner Brook (the same class of submarine as HMCS Chicoutimi).

The summer 2007 trial on HMCS Corner Brook (based on actigraphically-measured sleep (as opposed to sleep behaviour estimates that were use to support the Chicoutimi BOI)) demonstrated very worrisome levels of submariner cognitive effectiveness [1]. Essentially, the tactical submariners who were standing 6-hours on, 6-hours off, 6-hours on and 6-hours off were getting two minor sleep periods every 12 hours, each from 3 to 4 hours in duration. Within 24 hours of leaving port (HMNB Faslane) they were functioning at a cognitive effectiveness level equivalent to blood alcohol content (BAC) of 0.08%. Performance fell off steeply over the next 7 days at sea, bottoming out about at approximately 60% cognitive effectiveness. Operations at these degrees of fatigue lead to slips (erroneous execution of correct intentions) and errors (formation of erroneous intentions).

In September 2009, DRDC Toronto hosted an international submarine watch schedule symposium attended by the Royal Canadian Navy (RCN), Royal Navy (RN), Royal Australian Navy (RAN), Royal Netherlands Navy (RNLN) and the United States Navy (USN). During that symposium, we modeled a series of alternative submarine watch schedules for use in CF submarines. The best watch schedule was 'straight 8s, 1-in-3' which results in modeled cognitive effectiveness of about 96% and where each sailor works a single 8-hr daily watch thus allowing ample time for meals, training and personal admin and an 8-hour sleep opportunity. However, of the allies participating in this workshop, the only navy that could implement the 'straight 8s 1-in-3' was the USN, since even their small attack boats have between 130 to 150 submariners, and the USN Ballistic Missile submarines have even larger crews. Most of the other navies participating in this symposium have small attack boats with small crews which cannot implement 'straight 8s 1-in-3' due to small manning levels of their respective boats (standard crew on Cdn submarines is 48). These boats therefore must have their tactical submariners work a total of 12 hours per day.

The 12-hour watch schedule we optimized for CF submarines (8-4-4-8) involves 8-hours on, 8-hours off, 4-hours on, and 4-hours off. There is a watch change at 0400 h, thus sharing the nocturnal low point in alertness equally between the 2 watch syndicates (i.e., sharing between the port and starboard watches). The port watch works from 0400 h to 1200 h, and from 1600 h to 2000 h with prescribed sleep between 2100 h and 0300 h. The starboard watch works from 1200 h to 1600 h and from 2000 h to 0400 h with prescribed sleep from 0500 h to 1100 h. Average cognitive effectiveness for each of the port and starboard syndicates is about 90% [2]

The watch schedule used by the tactical sailors in our surface fleet is 7-5-5-7. This means that the sailors work a total of 12 hours each day but rather than one main sleep period, they have two shorter sleep periods. We believe that the 7-5-5-7 watch used by our surface fleet is better than the original 6-6-6-6- watch used in our submarines. However, from a fatigue management perspective, the current surface fleet watch system it is not as good as the new submarine watch (8-4-4-8). The CMS (Chief of Maritime Staff) office tasked HMCS St John's to support our evaluation of the watch scheduled employed on HMCS St John's (7-5-5-7) during the transit from the high Arctic (where HMSC St John's operated in support of Op Nanook, 2011) to Halifax. The results of this trial will inform our thinking as to possible improvements in the CF surface fleet watch schedule.

2 Trial Methodology

2.1 Duration of the trial

The trial on HMCS St John's (STJ) commenced shortly after the data collection team arrived from Pond Inlet via ship's helicopter at about 1800 h on August 24th, 2011. Within 45 minutes of arriving on the ship, the data collection team (first three authors) were distributing wrist actigraphs and 'activity, sleep and mood' logs to the sailors who were selected by the ship to participate as subjects in the trial. The trial ended when STJ arrived in Halifax in the afternoon of August 31st. While the elapsed time from start to end of the trial was 8 days, complete data was only collected from day 2 through day 7. Since only about half of the subjects provided 'activity, sleep and mood' data on days 1 and 8, data from days 1 and 2 were not sufficiently reliable for statistical analysis. However, based on the actigraph data, a FAST^{TM} model was made for each of the participating subjects.

2.2 Subject demographics

The ages of the 45 subjects ranged from 21 to 48 years, with a mean age and standard deviation of 32.9 ± 7.7 years. The 10 subjects who were non-watch-standers worked in various areas of the ship ranging from Combat Officer, Navigation Officer, Ops Room, Storesman, Cook, and various Engineering work spaces. There were 14 subjects working the 1-in-2 Port (Front) watch and 14 subjects working the 1-in-2 Starboard (Back) watch. Of the 14 subjects in the 1-in-2 Port Watch, 7 were working in the Ops Room and 5 were working on the Bridge, although 3 of these 5 Bridge personnel were splitting each of the 5-hour and 7-hour watches between the Bridge and the Ops Room. Of the 14 subjects in the 1-in-2 Starboard (Back) watch, 11 subjects were working in the Ops Room, and 3 were working on the Bridge, although 1 of the 3 bridge workers split each of the 5-hour and 7-hour watches between the Bridge and the Ops Room. There were also 3 subjects from the 1-in-3 Engineering watch (all from the Engine room work spaces), and 4 subjects from the 1-in-4 Engineering watch (also from the engine room work spaces). While FAST^{TM} models were made for each of the three 1-in-3 and four 1-in-4 Engineering watch subjects, there were insufficient numbers of these subjects to make systematic comparisons with either of the 1-in-2 watch syndicates.

2.3 Description of watch system variants

Both syndicates of the 1-in-2 watch system (i.e., Port and Starboard or Front Watch and Back Watch respectively) worked 5 hours and were off for 5 hours, and worked 7 hours and were off for 7 hours. The 1-in-2 Port watch duty hours were 0730 h to 1230 h and 1730 h to 0030 h, whereas the 1-in-2 Starboard watch duty hours were 1230 h to 1730 h and 0030 h to 0730 h.

The Engineering watch periods were as follows; 2330-0330 h middle watch, 0330-0730 h morning watch, 0730-1130 h forenoon watch, 1130-1530 h afternoon watch, 1530-1730 h first dog watch, 1730-1930 h last dog watch, and 1930-2330 first watch. Both the 1-in-3 and 1-in-4 Engineering watches used these watch times.

2.4 Data sets collected

In addition to wrist actigraph sleep data and daily watch-standing hours for use in the generation of cognitive effectiveness models with the FAST™ modelling program, the 45 sailors who participated as subjects in this trial made daily inputs into a sleep/activity/mood log. The log had provisions for the recording of daily sleep times (to cover for the possibility of actigraph failure), daily subjective sleep ratings, and daily indices of alertness and mood. The log also had a SOAP (Sustained Operations Assessment Profile (SOAP)) questionnaire [3] which was completed twice during the trail (once at the beginning of the trail and once at the end). The SOAP involved subjective assessments of 10 parameters covering three broad areas of functioning including cognitive, affective, and arousal dimensions, such as the ability to concentrate, boredom, performance, anxiety, depression, irritability, fatigue and sleep parameters, work frustration and physical discomfort.

2.5 FAST™ Modelling Program

A description of the FAST™ is provided in Annex F. FAST™ graphs are shown in Annex A for the non-watch-standers, Annex B for the 1-in-2 Port (front) watch-standers, Annex C for the 1-in-2 Starboard (back) watch-standers, Annex D for the 1-in-3 Engineering watch-standers and Annex E for the 1-in-4 Engineering watch-standers. Some details regarding these graphs are as follow:

- The vertical axis on the left side of the FAST™ graphs represents human cognitive performance effectiveness as a percentage of optimal performance (100%). The oscillating line in the diagram represents average performance (cognitive effectiveness) as determined by time of day, biological rhythms, time spent awake, and amount of sleep.

- The dotted line which is below the cognitive effectiveness represents the 10th percentile of cognitive effectiveness.

- The green band (from 90% to 100%) represents acceptable cognitive performance effectiveness for workers conducting safety sensitive jobs (flying, driving, weapons operation, command and control, etc). This is the usual level of effectiveness at evening bedtime following 16 hours of continuous daytime wakefulness.

- The yellow performance band (from 65% to 90% cognitive effectiveness) indicates caution. Personnel engaged in skilled performance activities such as aviation, should not be allowed to operate in this band.

- The area from the dotted line to the pink area represents the cognitive effectiveness equivalent to the circadian nadir and a 2nd day without sleep.

- The pink performance band (below 65%) represents performance effectiveness after 2 days and a night of sleep deprivation. Under these conditions, no one can be expected to function well on any task.

- The vertical axis on the right side of the FAST™ graphs represents the Blood Alcohol Content (BAC) equivalency throughout the spectrum of cognitive effectiveness. A value of 77% cognitive effectiveness corresponds to a blood alcohol content of 0.05% (legally impaired in some jurisdictions). A value of 70% cognitive effectiveness corresponds to a blood alcohol content of 0.08% (legally impaired in most jurisdictions). These BAC equivalency levels associated with sleep deprivation/fatigue are based on three important studies [4-6].

- The abscissa (x-axis) illustrates periods of work (red bars), sleep (blue bars), darkness (gray bars), and time of day in hours. The software includes a geophysical model that adjusts daylight and darkness estimates for latitude, and longitude and season.

2.6 Statistical analysis of subjective data

2.6.1 Sleep ratings

Each day, on a scale of 1 to 5, the subjects were asked to rate their difficulty falling asleep, their depth of sleep, their difficulty arising from sleep, and how rested they felt after sleep. Such 'ordinal data' is not normally distributed and was therefore analysed via non-parametric statistics. The Kruskal-Wallis analysis was used to assess group differences, and the Friedman Analysis of Variance (ANOVA) to test repeated measures across days. The Wilcoxon test was also used to assess matched pairs of ratings.

2.6.2 Visual Analogue Scale (VAS) ratings

The daily visual analog scales (VAS) tracked the following 8 parameters; alertness, sadness, tension, effort, happiness, weariness, calmness, and sleepiness. The subjects were presented with a 100 mm line for each parameter and were asked to indicate their subjective assessments related to each parameter by making a small vertical mark through the appropriate point in the line. The point at which the vertical mark was made in the line was measured and recorded. For example, a mark at 85 mm from the left-hand end of the line would yield a score of 85. Since these data are from a continuous scale (i.e., from 0 to 100) they were considered to be normally distributed and thus analysed by standard parametric means. A split-plot ANOVA with 3 between factors (i.e., 3 different watch system variants (non-watch standers, 1-in-2 Starboard (Back) watch and 1-in-2 Port (Front) watch)) and 6 repeated measures (i.e., 6 days at sea) was used.

2.6.3 SOAP ratings

Similar to the subjective sleep ratings, the SOAP profile was completed twice; once at the beginning of the trial and once at the end of the trial. Similar to the subjective sleep assessments, the subjects were tasked to rate their SOAP assessments (measures of concentration, boredom, slowed reactions, anxiety, depression, irritability, fatigue, poor sleep, work frustration, and physical discomfort) on a scale of 1 to 5. Each of these 10 parameters included 9 sub-parameters, each of which could be scored as 1 to 5. Therefore, the composite score for each parameter (e.g., concentration) could range from 9 (if each sub-parameter was scored as a '1') to 45 (if each parameter was scored as '9'). Since these interval data are not normally distributed, they were

analysed with the same non-parametric methods as the subjective sleep ratings: i.e., Kruskal-Wallis analysis to assess group differences, Friedman ANOVA to assess the 2 levels of repeated measures (pre- trial vs. post- trial), and the Wilcoxon test to assess matched pairs of cells.

2.6.4 Statistical Power

The powers of the various two-tailed statistical tests we estimated for $p = 0.10$ (which is appropriate for field studies), an effect size of 1 standard deviation, and a test-retest reliability for repeated measures of $r = 0.50$. The estimates were:

- ANOVA between groups. $n = 10$: 69% [7]
- ANOVA across days (repeated measures), $n=10$: 92% [7]
- Kruskal-Wallis between groups: 95.5% of the power of the F-test; thus, about 66% here
- Friedman repeated measures : about the same as the F-test, thus about 92% here [8]
- Wilcoxon repeated measures: 95.5% of the power of the t-test: thus about 88% here [8]

3 Results

3.1 Cognitive effectiveness of the Non-Watch-Standers

The FAST ™ models representing the predicted cognitive effectiveness of the 10 non-watch-standing subjects are illustrated in Annex A. To illustrate how cognitive effectiveness changes over time at sea, the mean daily duty cognitive effectiveness of these individuals is shown in Table 1.

Table 1. Cognitive effectiveness of non-watch-standers from Pond Inlet to Halifax

	Daily Mean duty % cognitive effectiveness							
Subject	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Day 8**
Storesman		96	88	87	76	66	54	
Storesman		94	88	91	89	83	78	
Cook		88	89	83	91	79	74	
Clerk		93	82	86	83	79	78	
Combat O		94	91	89	84	84	78	
Navigation O		96	91	90	91	91	87	
Ops Room		91	83	84	79	79	77	
Engineer		91	75	81	82	80	75	
Engineer		80	83	76	75	80	75	
Engineer		97	95	89	83	87	86	

77.5% cognitive effectiveness equates to a blood alcohol content of 0.05%
70% cognitive effectiveness equates to a blood alcohol content of 0.08%

(yellow) = 0.05% or higher blood alcohol content equivalent
(red) = 0.08% or higher blood alcohol content equivalent

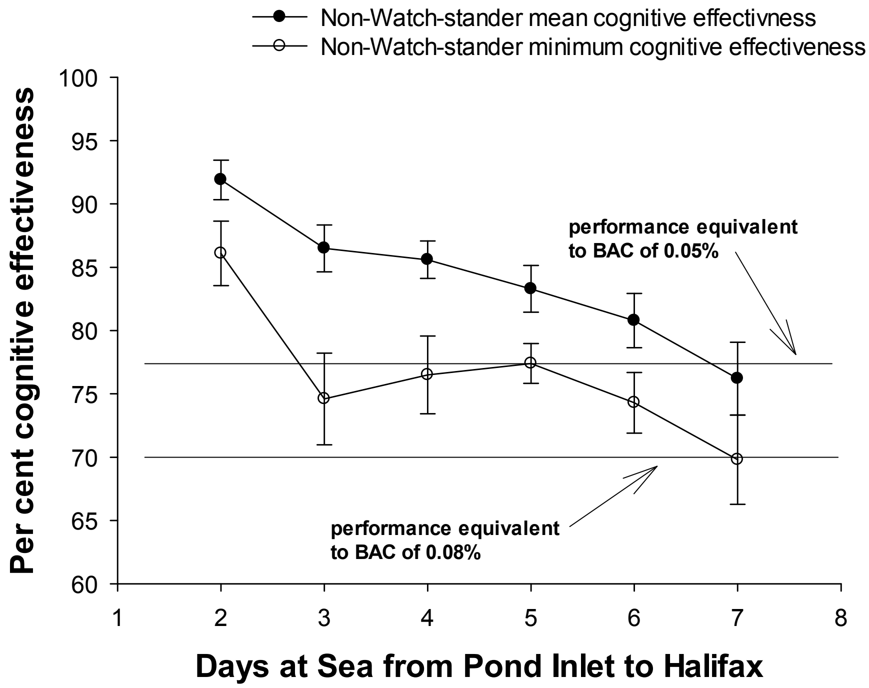


Figure 1. Mean and minimum cognitive effectiveness over days at sea for non-watch-stander, work periods. Solid circles are mean values ± s.e.m. and open circles are minimum cognitive effectiveness values ± s.e.m.

Of the 10 non-watch-stander subjects reported here, five avoided drops in cognitive effectiveness equivalent to intoxicated levels of BAC (blood alcohol content). The remaining five non-watch-stander subjects all reached cognitive effectiveness levels in excess of BAC 0.05%, and one of these 5 subjects exceeded 0.08% BAC. It is not known whether the 5 subjects whose cognitive effectiveness reached equivalence to intoxicated levels of BAC due to work demands that systematically denied them sleep opportunities or if their self-selected sleep times were inadequate to preclude such deficits. The group mean cognitive effectiveness attained BAC slightly in excess of 0.05% on day 7 (the last day of this trial). However, the group minimum cognitive effectiveness was in excess of BAC equivalent to 0.05% from days 2 to 6 inclusive and reached 0.08% on day 7.

3.2 Cognitive effectiveness of the 1-in-2 Port (Front watch) watch-standers

The FAST ™ models representing the predicted cognitive effectiveness of the 1-in-2 Port (Front watch) watch-standers are illustrated in Annex B. To show how cognitive effectiveness changes over time at sea, the mean daily duty cognitive effectiveness of these individuals is illustrated in Table 2.

Table 2. Cognitive effectiveness of 1-in-2 Port (front watch) watch-standers from Pond Inlet to Halifax

		Daily mean duty cognitive effectiveness							
Subject I.D. #	**Shift time**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Day 8**
3	0730-1230 h		95	75	85	85	83	82	
4	0730-1230 h		94	91	90	87	89	87	
7	0730-1230 h		99	95	92	94	89	92	
10	0730-1230 h		99	97	91	93	89	92	
11	0730-1230 h		99	94	81	85	85	86	
17	0730-1230 h		99	96	93	91	90	83	
18	0730-1230 h		99	92	77	79	84	83	
21	0730-1230 h		99	93	81	70	65	73	
24	0730-1230 h		99	96	92	93	92	89	
26	0730-1230 h	cognitive effectiveness not available – actigraph failure							
31	0730-1230 h		96	85	74	77	86	78	
34	0730-1230 h		93	86	84	75	69	68	
36	0730-1230 h		94	89	86	83	86	82	
47	0730-1230 h		93	86	84	75	69	68	
3	1730-0030 h		94	84	88	88	89	88	
4	1730-0030 h		95	93	90	93	90	93	
7	1730-0030 h		99	98	97	94	93	98	
10	1730-0030 h		98	98	96	95	96	96	

11	1730-0030 h		98	95	86	87	92	92	
17	1730-0030 h		97	94	95	94	94	89	
18	1730-0030 h		98	93	83	83	89	88	
21	1730-0030 h		97	94	82	73	76	76	
24	1730-0030 h		97	95	95	96	91	90	
26	1730-0030 h	cognitive effectiveness not available – actigraph failure							
31	1730-0030 h		98	96	90	73	87	85	
34	1730-0030 h		92	86	83	83	73	73	
36	1730-0030 h		92	90	86	86	85	87	
47	1730-0030 h		92	86	83	83	73	73	

77.5% cognitive effectiveness equates to a blood alcohol content of 0.05%
70% cognitive effectiveness equates to a blood alcohol content of 0.08%

(yellow) = 0.05% or higher blood alcohol content equivalent
(red) = 0.08% or higher blood alcohol content equivalent

Mean and minimum cognitive effectiveness for both of the 1-in-2 Port (front-watch) work periods are illustrated in Figure 2. Note the decrease in cognitive effectiveness from days 2 to 4, probably due to inadequate sleep quality and/or quantity.

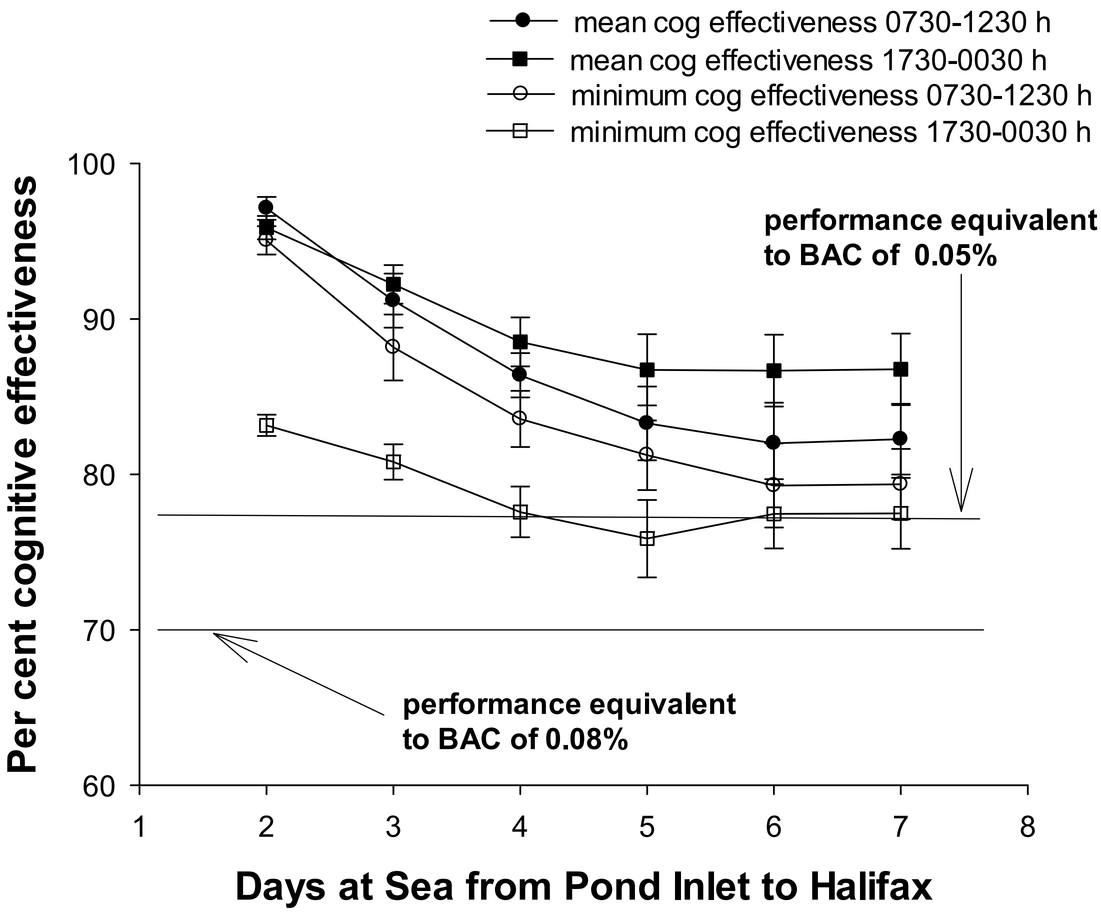


Figure 2. Mean and minimum cognitive effectiveness over days at sea for both of the 1-in-2 front watch, work periods. Solid circles and squares are mean values ± s.e.m. and open circles and squares are minimum cognitive effectiveness values ± s.e.m.

Based on Table 2 and Figure 2 (relative to the corresponding tables (1 and 3) figures (1 and 3) for the non-watch standers and the 1-in-2 Starboard (Back) watch, it is clearly evident that the 1-in-2 Port (Front) watch-standers had the least impacted performance of the 3 groups we were able to compare. This suggests that the 1-in-2 Port (Front) watch work hours were far less provocative to sailor performance than the 1-in-2 Starboard (Back) watch-standers.

3.3 Cognitive effectiveness of the 1-in-2 Starboard (Back-watch) watch-standers

The FAST[TM] models representing the predicted cognitive effectiveness of the 1-in-2 Starboard (Back-watch) watch standers are illustrated in Annex C. To show how cognitive effectiveness changed over time, the mean daily duty cognitive effectiveness of these individuals is illustrated in Table 3.

Table 3. Cognitive effectiveness of 1-in-2 Starboard (back watch) watch-standers from Pond Inlet to Halifax

		Daily mean duty cognitive effectiveness							
Subject I.D.#	**Shift time**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Day 8**
6	1230-1700 h		91	82	76	70	71	74	
9	1230-1700 h		89	77	69	75	73	55	
12	1230-1700 h		91	82	84	80	80	78	
15	1230-1700 h		91	82	84	80	80	78	
20	1230-1700 h		87	81	71	79	73	59	
23	1230-1700 h		94	87	83	79	80	79	
25	1230-1700 h		92	88	75	79	77	82	
27	1230-1700 h		92	90	79	81	75	74	
28	1230-1700 h		89	81	76	63	71	65	
29	1230-1700 h		80	71	76	72	73	76	
35	1230-1700 h		91	87	76	77	79	78	
40	1230-1700 h		86	84	84	81	80	62	

44	1230-1700 h		93	88	85	82	83	80	
45	1230-1700 h		92	89	80	78	75	77	
6	0030-0730 h		82	73	72	68	59	65	
9	0030-0730 h		80	64	58	61	66	58	
12	0030-0730 h		81	68	72	74	73	74	
15	0030-0730 h		81	67	66	65	66	59	
20	0030-0730 h		82	70	67	63	66	55	
23	0030-0730 h		84	69	74	59	66	70	
25	0030-0730 h		82	74	67	65	63	73	
27	0030-0730 h		84	75	67	66	61	56	
28	0030-0730 h		83	71	66	64	56	56	
29	0030-0730 h		75	66	61	54	69	65	
35	0030-0730 h		81	77	75	60	67	65	
40	0030-0730 h		75	66	68	70	62	63	
44	0030-0730 h		84	77	74	71	72	66	
45	0030-0730 h		81	77	71	63	66	64	

77.5% cognitive effectiveness equates to a blood alcohol content of 0.05%
70% cognitive effectiveness equates to a blood alcohol content of 0.08%

(yellow) = 0.05% or higher blood alcohol content equivalent
(red) = 0.08% or higher blood alcohol content equivalent

Mean and minimum cognitive effectiveness for both of the 1-in-2 Starboard (back-watch) work periods are illustrated in Figure 3. Note the mean and minimum cognitive effectiveness values are generally well below BAC 0.08%, due to inadequate sleep quality and/or quantity. This level of cognitive effectiveness is in the pink zone of the FAST^{TM} models (see Annex C for the 1-in-2 Stbd (back watch models). Cumulative fatigue builds up across major work periods where there is inadequate recovery (due to inadequate sleep) between waking periods. Recovery from cumulative fatigue cannot be accomplished in one good-quality sleep period. One very important aspect of cumulative fatigue is sleep debt.

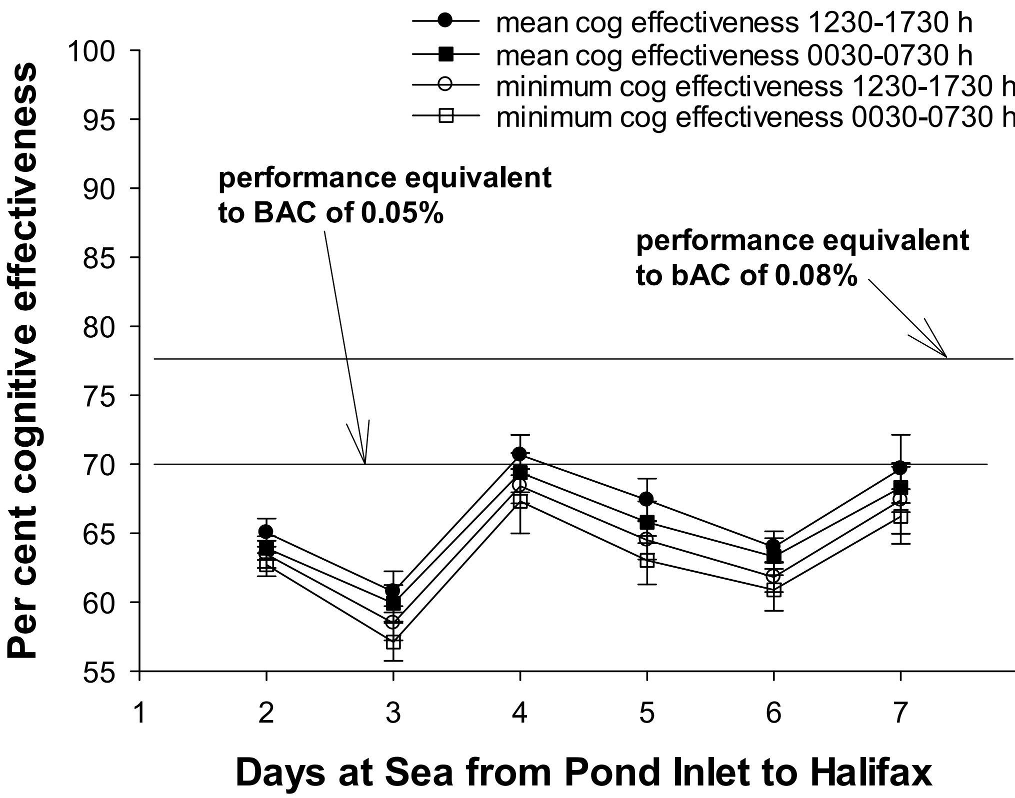


Figure 3. Mean and minimum cognitive effectiveness over days at sea for both of the 1-in-2 back watch, work periods. Solid circles and squares are mean values ± s.e.m. and open circles and squares are minimum cognitive effectiveness values ± s.e.m.

3.4 Cognitive effectiveness of Engineering watch-standers

We had three subjects from the 1-in-3 Engineering watch, all of which were from the Engine Room. We also had four subjects from the 1-in-4 Engineering watch, all of which were from the Engine room work spaces. Two of the three subjects from the 1-in-3 Engineering watch were

from the ‘red’ syndicate. However the 3rd subject from the 1-in-3 Engineering watch did not specify which syndicate he belonged to. Of the four 1-in-4 Engineering watch subjects, two were from the 1-in-4 Port syndicate and two were from the 1-in-4 Starboard syndicate.

As mentioned previously, the 7 work periods used in the 1-in-3 Engineering watch were also used in the 1-in-4 Engineering watch. However, on any given day, we were not aware of the specific watches stood by any of these 7 Engineering watch subjects. We contacted the ship’s office (HMCS St John’s) ten months after the data collection in a quest to obtain the exact *daily* watch times stood by each of these 7 subjects. At that time, the ship no longer had these records. Therefore, we were obliged to set up work periods in the FAST™ models based on actigraphically measured sleep times, in the following manner: one hour before and one hour after each sleep period was used as a transition to and from sleep, thus allowing an hour to obtain a meal and relax before and after each sleep or nap. Multiple daily work periods were averaged into a single daily mean and a single daily minimum work period cognitive effectiveness value.

The FAST™ models representing the predicted cognitive effectiveness of the 1-in-3 Engineering watch-standers are illustrated in Annex D. To show how cognitive effectiveness changes over time at sea, the mean daily duty cognitive effectiveness of these individuals is illustrated in Table 4. The corresponding FAST™ models and cognitive effectiveness Table for the 1-in-4 Engineering watch are illustrated in Annex E and Table 5, respectively.

3.4.1 1-in-3 Engineering watch

Table 4. Cognitive effectiveness of 1-in-3 Engineering watch-standers from Pond Inlet to Halifax

	Daily mean duty cognitive effectiveness over days at sea							
Subject I.D. #	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Day 8**
13	91	82	76	68	77	64	91	82
38	83	77	82	67	70	69	83	77
48	87	81	76	79	85	72	87	81

77.5% cognitive effectiveness equates to a blood alcohol content of 0.05%
70% cognitive effectiveness equates to a blood alcohol content of 0.08%

(yellow) = 0.05% or higher blood alcohol content equivalent
(red) = 0.08% or higher blood alcohol content equivalent

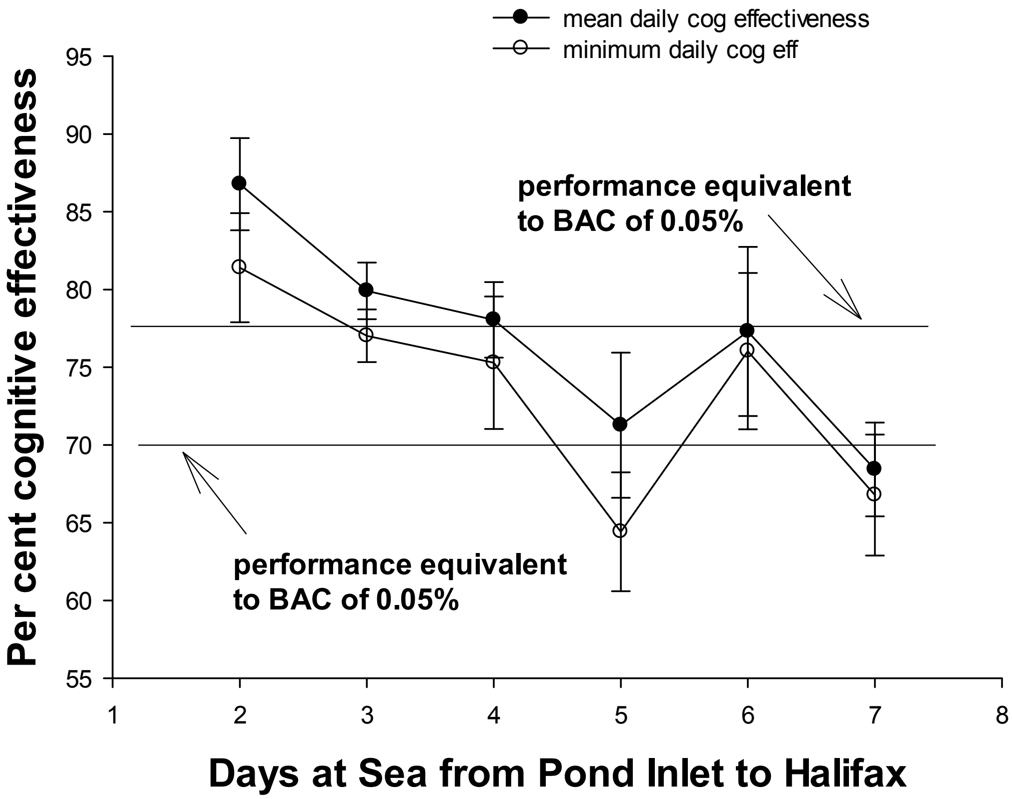


Figure 4. Mean and minimum cognitive effectiveness over days at sea for the 1-in-3 Engineering watch, work periods. Solid circles are mean values ± s.e.m. and open circles are minimum cognitive effectiveness values ± s.e.m.

While Figure 4 indicates that days 5 and 7 resulted in the lowest cognitive effectiveness for the 1-in-3 Engineering subjects, it is difficult to make any further comments since there were only 3 subjects in this group. Such small numbers of subjects in this group precludes any systematic comparison with the larger subject groups (non-watch standers, 1-in-2 Port (Front) watch and 1-in-2 Starboard (Back) watch.

3.4.2 1-in-4 Engineering watch

Table 5. Cognitive effectiveness of 1-in-4 Engineering watch-standers from Pond Inlet to Halifax

	Daily mean duty cognitive effectiveness over days at sea							
Subject I.D. #	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Day 8**
42	81	74	66	75	63	59	81	74
46	86	79	86	81	75	63	86	79
49	85	70	72	77	61	62	85	70
51	80	78	72	67	65	64	80	78

77.5% cognitive effectiveness equates to a blood alcohol content of 0.05%
70% cognitive effectiveness equates to a blood alcohol content of 0.08%

(yellow) = 0.05% or higher blood alcohol content equivalent
(red) = 0.08% or higher blood alcohol content equivalent

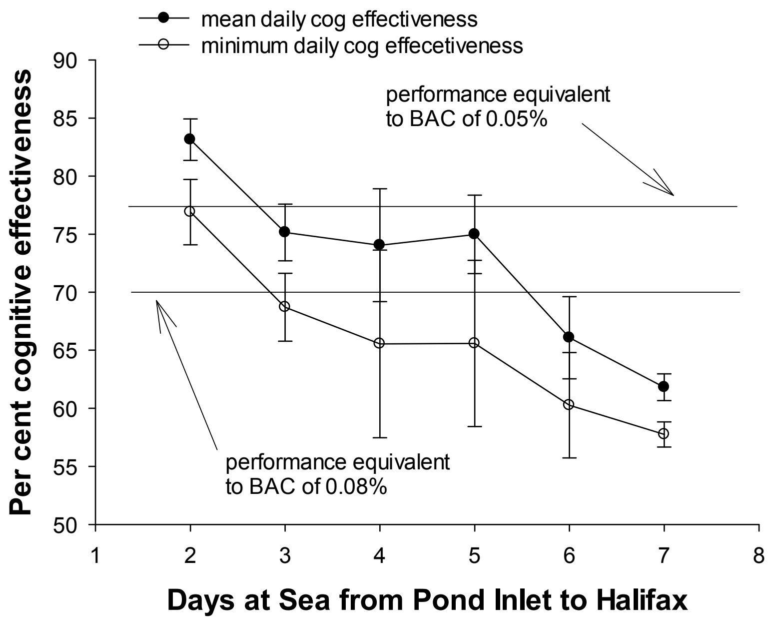


Figure 5. Mean and minimum cognitive effectiveness over days at sea for the 1-in-4 Engineering watch, work periods. Solid circles are mean values ± s.e.m. and open circles are minimum cognitive effectiveness values ± s.e.m.

While Figure 5 indicates that the 1-in-4 Engineering watch subjects were “impaired” with fatigue for most of the trial and reached levels of cognitive effectiveness well beyond BAC of 0.08%again, it is difficult to make any further comments since there were only 4 subjects in this group, thus precluding any systematic comparison with the larger subject groups (non-watch standers, 1-in-2 Port (Front) watch and 1-in-2 Starboard (Back) watch.

3.5 Subjective Sleep/Activity and Mood log data

Since there were only three 1-in-3 Engineering and four 1-in-4 Engineering watch subjects, the data from these 7 Engineering watch subjects are not represented in any of the 3 subjective data sets (sleep ratings, visual analogue mood ratings and SOAP ratings).

3.5.1 Sleep ratings

On a scale of 1 to 5, the subjects were asked to rate their difficulty falling asleep, their depth of sleep, their difficulty arising from sleep, and how rested they felt after sleep.

3.5.1.1 "Difficulty getting to sleep'

The data showing 'difficulty arising from sleep' over days at sea across the non-watch-standers, is illustrated in Figure 6. Data from Figure 6 is collapsed over days and is plotted as Figure 7.

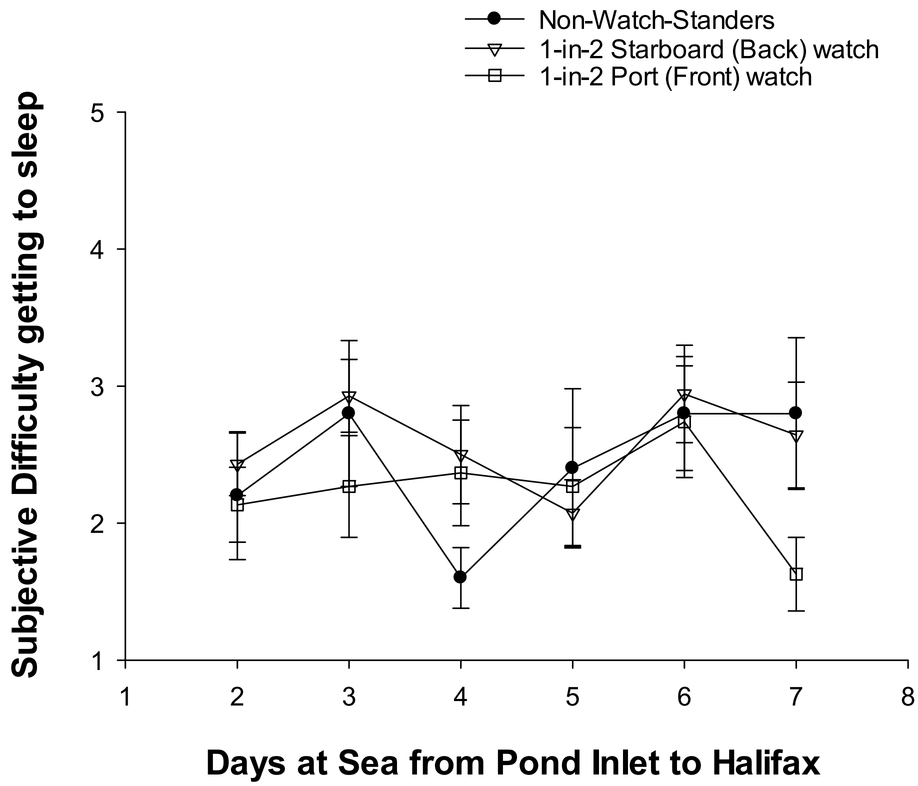
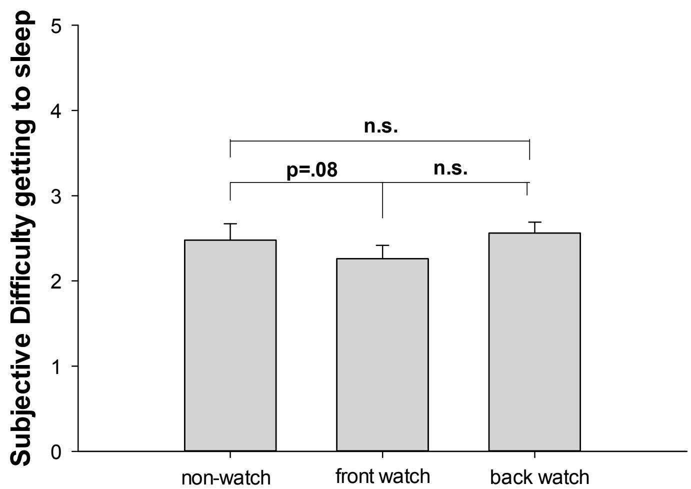


Figure 6. Mean difficulty getting to sleep over days at sea for the non-watch-standers, the 1-in-2 starboard (Back) watch and the 1-in-2 Port (Front) watch, work periods. Solid circles are non-watch-standers, open triangles are 1-in-2 Back watch, and open squares and 1-in-2 Front watch. All values are means ± s.e.m.

The Kruskal-Wallis test confirmed that there are differences between groups in "difficulty getting to sleep' (Chi-square = 7.98, df = 2, p = 0.02). The Friedman ANOVA indicates no difference in difficulty getting to sleep over days at sea (Chi-square (N=38, df=5) = 7.99, p = .15.



Days at Sea from Pond Inlet to Halifax

Figure 7. Main effect of groups for 'difficulty getting to sleep'. All values are mean ± s.e.m.

The Kruskal-Wallis post hoc test for Watch type indicates that the Front watch had slightly less difficulty getting to sleep relative to the non-watch standers and the 1-in-2 Back watch. ($H(2, N=8) = 6.34$, $p = 0.04$).

3.5.1.2 'Depth of sleep'

The data illustrating the 'depth of sleep' over days at sea are plotted in Figure 8.

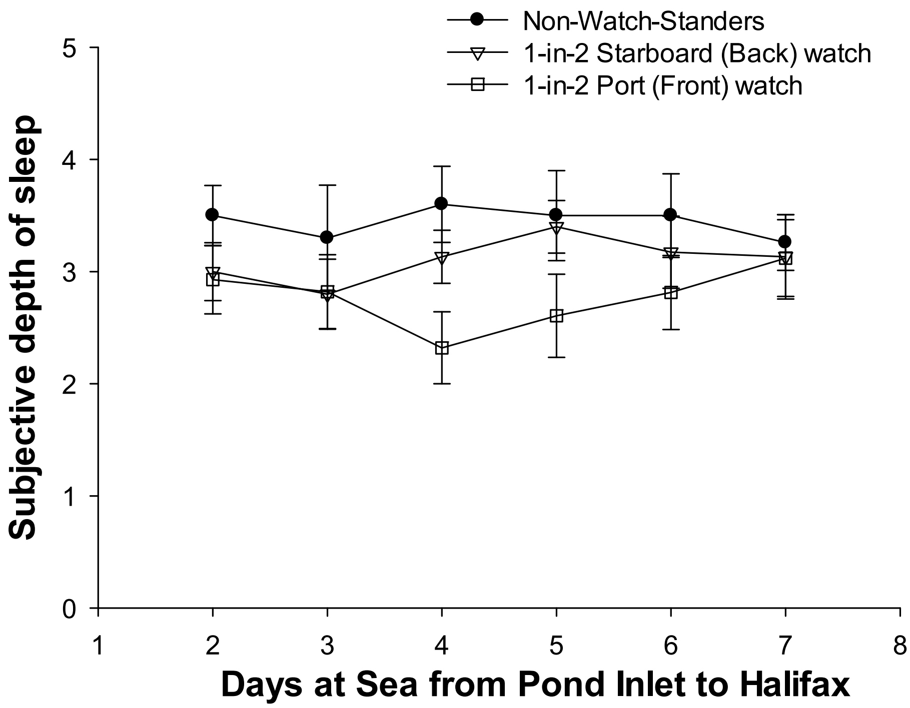


Figure 8. Mean depth of sleep over days at sea for the non-watch-standers, the 1-in-2 starboard (Back) watch and the 1-in-2 Port (Front) watch, work periods. Solid circles are non-watch-standers, open triangles are 1-in-2 Back watch, and open squares and 1-in-2 F Front watch. All values are means ± s.e.m.

The Kruskal-Wallis test indicates no difference in 'depth of sleep' between Non-Watch-Standers, 1-in-2 Back watch, and 1-in-2 Front watch, (Chi-square = 0.30, df = 2, p = 0.86). The Friedman ANOVA indicated no difference in 'depth of sleep' over days at sea, (Chi-square (n =3 8, df = 2) = 1.32, p = 0.93).

3.5.1.3 'Difficulty arising from sleep'

The data showing the difficulty arising from sleep over days at sea are plotted in Figure 9.

The Kruskal-Wallis test indicates no difference in 'difficulty arising from sleep' between the Non-Watch-Standers and the 1-in-2 Back watch and 1-in-2 Front Watch, (Chi-square = 1.67, df = 2, p = 0.43). The Friedman ANOVA indicates 'difficulty arising from sleep' did not change over days at sea (Chi-square (n =3 8, df = 5) = 3.76, p = 0.56).

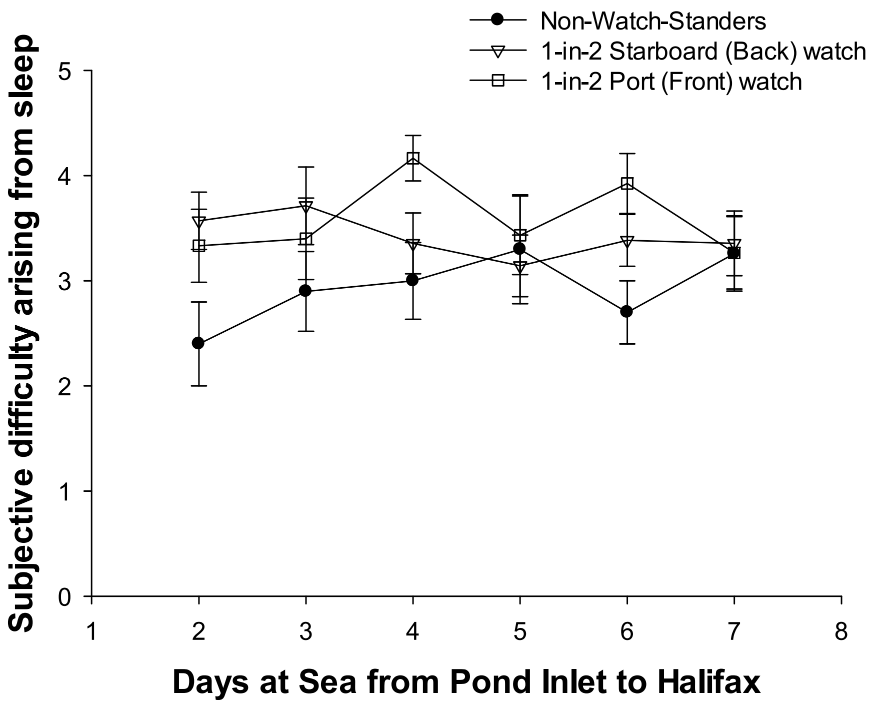


Figure 9. Mean 'difficulty arising from sleep' over days at sea for the non-watch-standers, the 1-in-2 starboard (Back) watch and the 1-in-2 Port (Front) watch, work periods. Solid circles are non-watch-standers, open triangles are 1-in-2 Back watch, and open squares and 1-in-2 Front watch. All values are means ± s.e.m.

3.5.1.4 ‘Restedness upon arising from sleep’

The data illustrating the level of ‘restedness upon arising from sleep’ are illustrated in Figure 10.

The Kruskal-Wallis test indicates no differences in ‘restedness’ between the Non-Watch-Standers, the 1-in-2 Back watch and the 1-in-2 Front watch, (Chi-square = 1.66, df = 2, p = 0.43). The Freidman ANOVA Chi-square indicates no differences in ‘restedness’ over days at sea (Chi-square (n = 38, df = 2) = 6.41, p = 0.27).

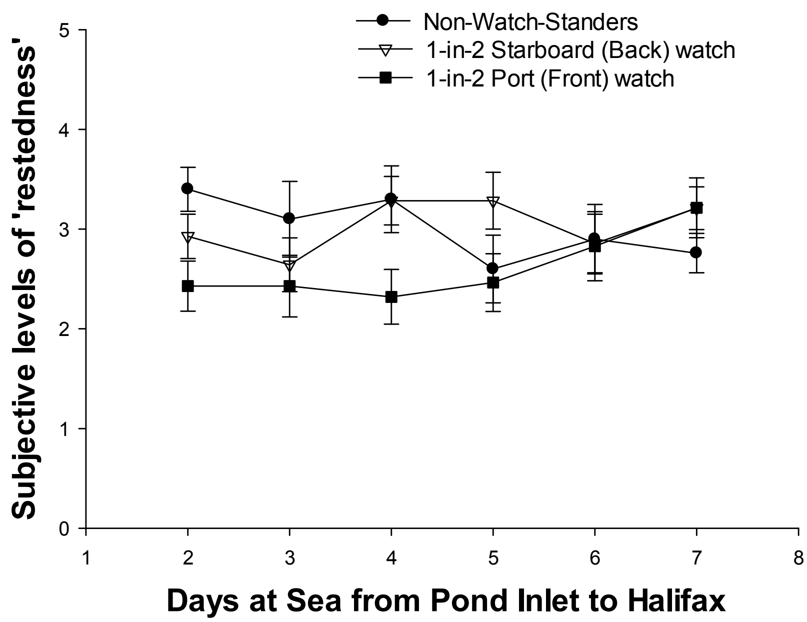


Figure 10. Mean levels of ‘restedness’ over days at sea for the non-watch-standers, the 1-in-2 starboard (Back) watch and the 1-in-2 Port (Front) watch, work periods. Solid circles are non-watch-standers, open triangles are 1-in-2 Back watch, and open squares and 1-in-2 Front watch. All values are means ± s.e.m.

3.5.2 VAS ratings

The daily VAS ratings tracked the following parameters; alertness, sadness, tension, effort, happiness, weariness, calmness, and sleepiness. Of these 8 parameters, only happiness showed any differences between groups. None of these 8 parameters showed any differences over days at sea. While the happiness data will be illustrated, the sleepiness data will also be illustrated to show that the subjects were consistently at elevated levels of sleepiness throughout this evaluation.

3.5.2.1 Happiness

The happiness data are illustrated in Figures 11 and 12. The 3 watch types (non-watch-standers, 1-in-2 Starboard (Back) watch and 1-in-2 Port (Front) watch) x days at sea repeated measures ANOVA indicated that the main effect of watch type was significant ($F(2,18) = 6.68$, $p<0.007$), the main effect of days at sea was not significant ($F(5,45) = 0.99$, $p<0.43$), and the watch type x days at sea interaction was not significant ($F(10,90)=1.33$, $p<0.23$).

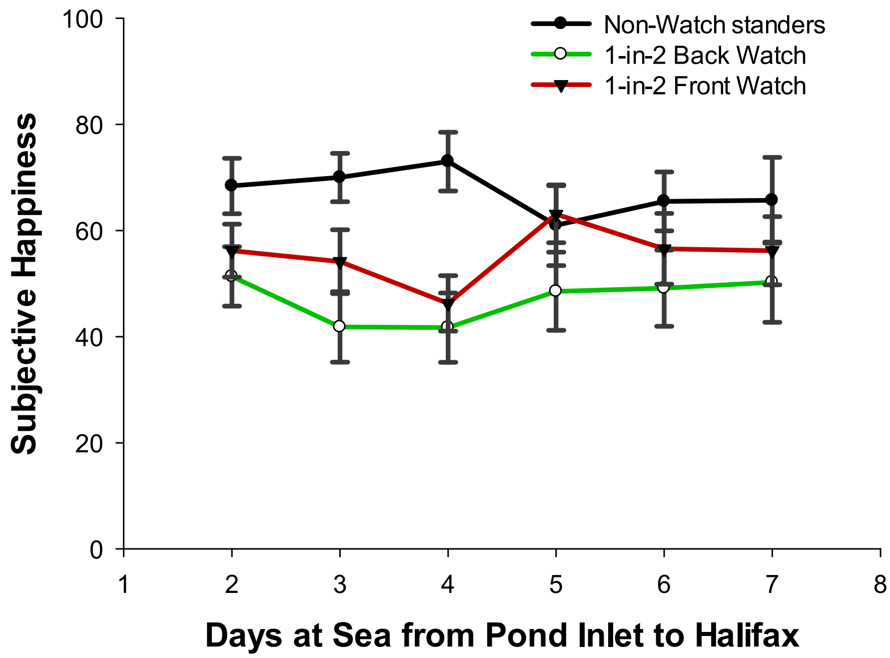


Figure 11 . Mean level of 'happiness' between watch types (non-watch-standers, 1-in-2 Starboard (Back) watch and 1-in-2 Port (Front) watch) over days at sea. All values are mean ± s.e.m.

To illustrate the significant effect of watch type on happiness, Figure 11 is collapsed over days at sea and is re-plotted in Figure 12. The LSD test was used for post hoc analysis of the main effect of watch type on happiness. The appropriate 'p values' comparing the 3 watch types for 'happiness' indicated that the non-watch-standers were in a happier mood than either of the 1-in-2 back or front watches.

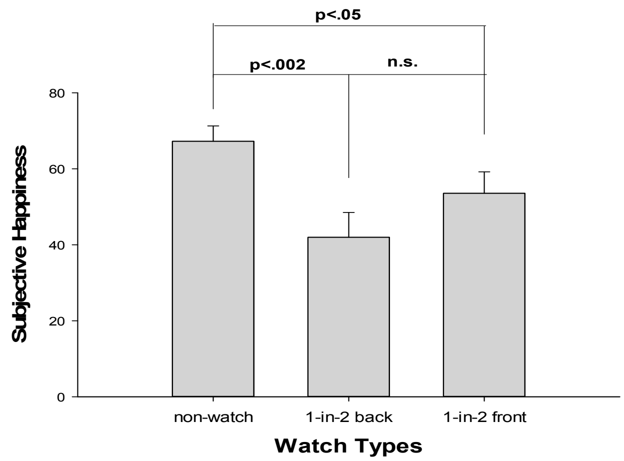


Figure 12 Mean level of 'happiness' as a function of watch type. All values are mean ± s.e.m.

3.5.2.2 Sleepiness

The sleepiness data are illustrated in Figure 13. The 3 watch types x days at sea repeated measures ANOVA indicated that the main effect of watch type was not significant ($F(2,18) = 4.02$, $p<0.32$), the main effect of days at sea was not significant ($F(5,46) = 0.26$, $p<0.93$), and the watch type x days at sea interaction was not significant ($F(10,90) = 1.03$, $p<0.42$), confirming that there were no differences in sleepiness between the 3 watch groups nor over days at sea. However, Figure 13 demonstrates the important observation that all three watch groups reported sleepiness in the middle of the sleepiness scale confirming that they were consistently quite sleepy.

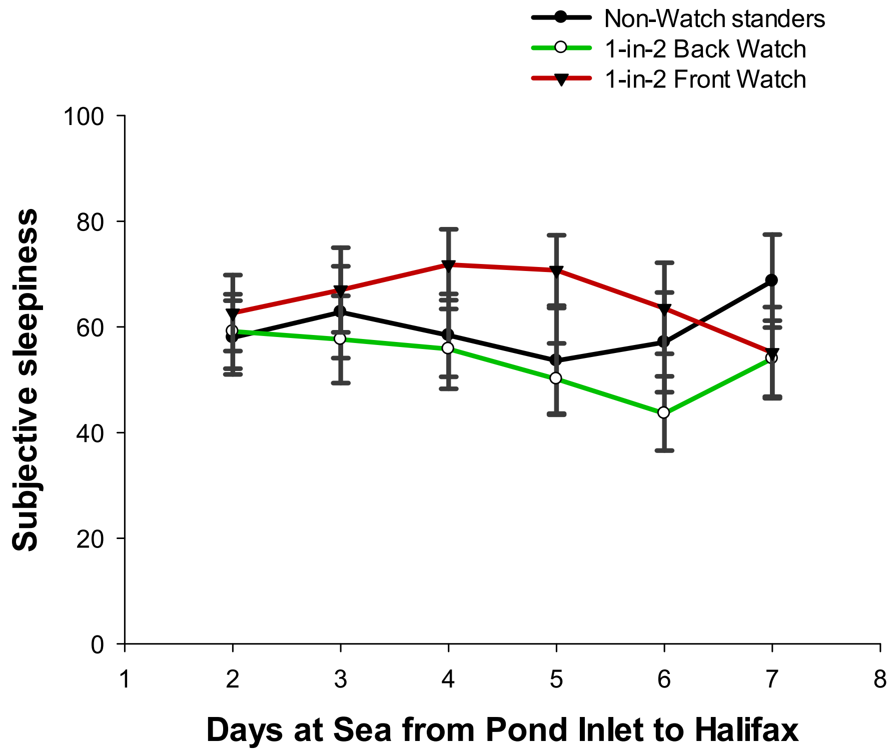


Figure 13 Mean level of 'happiness' between watch types (non-watch-standers, 1-in-2 Starboard (Back) watch and 1-in-2 Port (Front) watch over days at sea.All values are mean ± s.e.m.

3.5.3 SOAP ratings

The composite score for each of the 10 parameters (measures of concentration, boredom, slowed reactions, anxiety, depression, irritability, fatigue, poor sleep, work frustration, and physical discomfort) is illustrated in Figure 14.

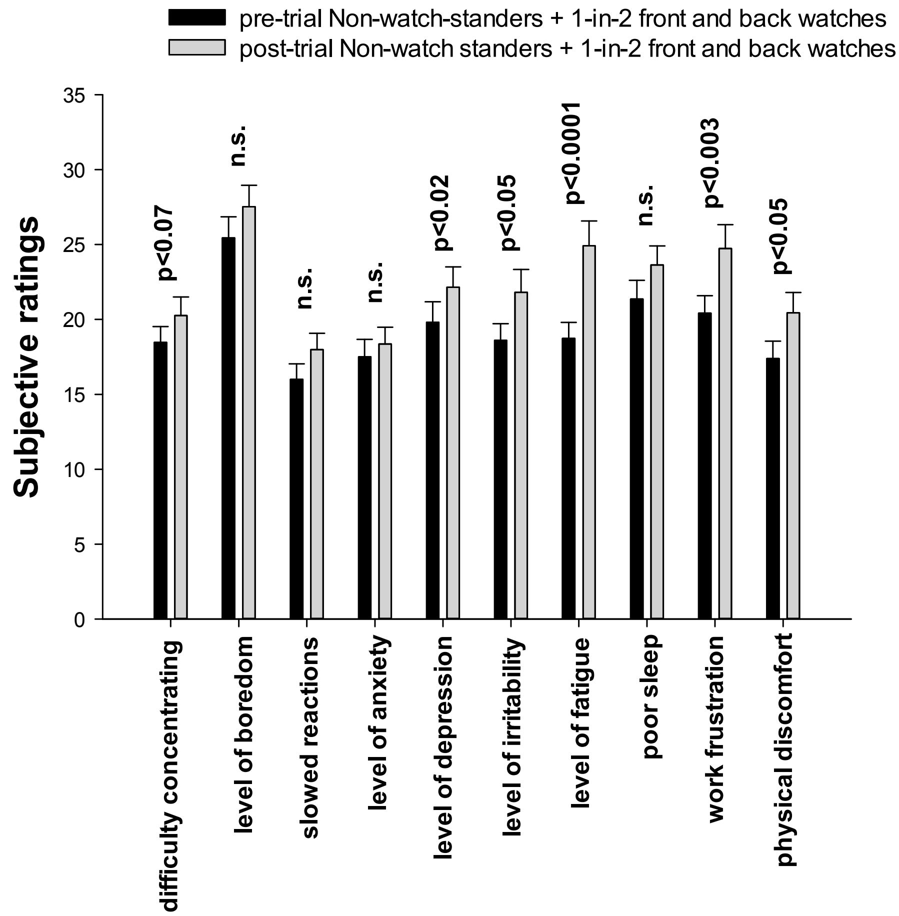


Figure 14 Mean levels of each of the 10 SOAP parameters pre- and post-trial collapsed over Non-watch-standers, 1-in-2 Starboard (Back) watch and 1-in-2 Port (Front) watch.All values are mean ± s.e.m.

The data from Subject 2 (a non-watch-stander) were not included in these analyses since he did not complete the SOAP pre-trial. The Kruskal Wallis test confirmed there were no group differences in any of the parameters (Chi-square = .18, df = 2, p = 0.91). The Friedman ANOVA indicates that there were significant pre-to-post trial changes in some of the parameters (Chi-Square (N = 38, df = 18) = 166.23, p =.000001). The Wilcoxon matched pairs test confirmed that the following 6 parameters had significantly deteriorated post-trial relative to pre-trial (difficulty concentrating (p<0.07), level of depression (p<0.02), level of irritability, (p<0.05) level of fatigue (p<0.0001), work frustration (p<0.003) and physical discomfort (p<0.05)). These data represent the consequences of fatigue accumulation over the trial.

4 Discussion

The results of this trial on HMCS St John's are not perfectly comparable to the trial we conducted on HMCS Corner Brook. Immediately prior to the trial on Corner Brook [1], the entire crew had been at shore near HMNB Faslane, for well over a month awaiting repairs to the SSEs (Submarine Signal Ejectors) before they could return to sea for the transatlantic passage to Halifax. Thus, the Corner Brook crew commenced their trial in a fully rested state. The crew on HMCS St John's had been at sea since early August and, in spite of a brief return to Halifax for repairs to an engine propeller shaft, had been a sea for almost 3 weeks before our data collection team arrived on the ship via ship's helicopter. This crew was already somewhat tired when the trial commenced.

Of the ten subjects who made up the non-watch standers of our subject population, five (a storesman, a clerk, the Combat Officer, the Navigation Officer and an Engineering technician) had sufficient sleep hygiene to avoid modeled cognitive effectiveness equivalent to intoxication with alcohol. Of the five remaining subjects, four (a cook, and Operations room technician, and two engineering technicians) had modeled cognitive effectiveness that reached between BAC 0.05% and BAC 0.08%, and one (another storesman) had cognitive effectiveness levels well beyond BAC of 0.08%. Figure 1 shows mean and minimum daily cognitive effectiveness levels averaged over all 10 non-watch-standers (Table 1). Average daily mean cognitive effectiveness reached below BAC 0.05% on the last day of the trial (day 7), while minimum daily cognitive effectiveness was in excess of BAC 0.05% on second day of the trail (day 3), and reached BAC 0.08% on day 7. It is possible that of the five non-watch-standers who reached levels of performance equivalent to significant BAC levels, some may have been called from their racks during their primary sleep periods. However, a review of the actigraph data for these subjects consistently indicates similar and inadequate sleep behaviours over days at sea. As in the civilian world, there are some military personnel who do not exhibit responsible sleep practices and/or good sleep hygiene. This results in their functioning at impaired levels of performance while they are on duty.

Of the 13 subjects from the 1-in-2 Port (Front) watch for whom we could generate FAST^{TM} five reached impaired levels of BAC during their 0730 h-1230h work period and four of these 13 subjects reached impaired levels of BAC during their 1730h-0030h work period (Table 2). Over all 13 subjects, average mean daily cognitive effectiveness levels did not reach impaired levels of cognitive effectiveness. However, averaged daily minimum cognitive effectiveness levels reached BAC of 0.05% on days 4-7 for the 1730h-0030h work period only (Figure 2).

In contrast, of the 14 subjects in the 1-in-2 Starboard (Back) watch, nine subjects reached impaired levels of cognitive effectiveness during the 1230h-1700 h watch and all 14 subjects reached impaired levels of cognitive effectiveness during their 0030h-0730h work period (Table 3.) Average mean and minimum cognitive effectiveness levels for both work periods of the 1-in-2 Starboard (Back) watch were consistently below BAC 0.08% over all trial days at sea. It is evident that the 0030h-0730h work period is especially provocative in terms of modeled cognitive effectiveness. This work period should be split equally between the Port (Front) and Starboard (Back) watch syndicates with a watch change at 0400 h, similar to the new RCN submarine watch schedule. Please see Paul *et al.* [2] for the details.

Each of the 3 1-in-3 Engineering watch subjects reached modeled cognitive effectiveness levels equivalent to impaired levels of BAC (Table 4, and Figure 4). Similarly, each of the 1-in-4 Engineering watch subjects also reached modeled cognitive effectiveness levels equivalent to impaired levels of BAC (Table 5 and Figure 5). As mentioned previously, there were too few engineering subjects to compare statistically to the other watch system variants. Further, since we could not determine which of the 7 engineering work periods were worked by each subject at any point in time, and the ship could not provide granularity of those details, unlike the Technical Report detailing the findings of the Submarine watch schedule [1] we cannot assess the impact of each of the 7 engineering work periods on modeled cognitive effectiveness.

With respect to the sleep rating data, the depth of sleep ratings was just above half scale and there were no group differences or differences over days at sea. Similarly, ratings for difficulty arising from sleep and level of restedness were both slightly above half scale with no group differences or differences over days at sea. It is evident that everyone was tired, although we found that there wasn't much difficulty getting to sleep since the subjects were so tired (Figure 6). However, post-hoc analysis of the significant main effect of groups indicates that the 1-in-2 front watch had slightly less difficulty getting to sleep relative to the non-watch standers.

For the SOAP rating data, six of the ten parameters (difficulty concentrating, level of depression, level of fatigue, work frustration and physical discomfort) showed deteriorated levels at the end of the trial, relative to the beginning of the trial.

In summary, we conclude that half of the non-watch-standers did not manage to obtain sufficient sleep and were working at impaired levels of cognitive effectiveness. This could be avoided by better sleep practices and/or sleep hygiene. We also conclude that of the two 1-in-2 watch syndicates, during work periods, the back watch was much more impaired than the front watch. The mitigation strategy in this case would be to re-arrange the work periods of the 1-in-2 watch to equitably distribute the nocturnal work liability (i.e. during Window Of Circadian Low (WOCL)) over both watches with a watch change at 0400 h. The 1-in-2 watch system would be further improved by moving from 7-on, 7-off, 5-on, 5-off to 8-on, 8-off, 4-on and 4-off. The 8-hour off period could be used for a 6-hour sleep period, which would significantly improve modeled cognitive effectiveness of both front and back watch syndicates of the 1-in-2 watch system. See Paul *et al*. [2] for the details.

Overall, we observed levels of fatigue and sleepiness among crew members inconsistent with the safe operation of a vessel at sea. This is not an unusual observation [9]. In a previous study, we observed that commanders of some US. Coast Guard cutters offset cumulative fatigue by ceasing both underway operations (i.e., the cutter was tied to a pier) and watchstanding for one night about once every ten days to allow watchstanders to acquire nocturnal recovery sleep [10]. Similarly, we learned at the DRDC-Toronto international submarine watch schedule symposium that some submarine commanders in various navies have set the vessel on the sea floor occasionally to allow watchstanders to acquire recovery sleep.

ON USCG cutters, each watch station is billeted for three watchstanders. In some cases, only two crewmembers are qualified to stand that watch when the cutter gets underway. We observed that when only two crewmembers were available to stand a specific watch position, the qualified personnel used 6- or 12-h (port and starboard) watches, as in the present trial [10]. In this 1-in-2 schedule, the qualified crew members were awakened at times from recovery sleep to perform

portions of their job(s), contributing to the cumulative fatigue. It was standard practice to qualify a third watchstander as soon as possible once underway to enable moving to a 1-in-3 schedule.

5 Recommendations

The very best watch schedule changes for the tactical sailors who stand the 1-in-2 watches would be to move to a straight 8s 1-in-3 system where a single 8-hours watch is worked each day. This would leave 8 hours for meals, training and personal administration and an 8-hour time in bed. Further the three 8-hour work periods should be 1200-2000h, 2000-0400h and 0400h-1200h. This would distribute the work during the WOCL across two watch syndicates. See these detail is Paul *et al.* [2]. Since we are not familiar with current RCN manning levels for sea billets or with the Force Development aspects of the Naval Sea Training system, we do not know if a straight 8s 1-in-3 system is do-able in the RCN context.

In the event that the RCN cannot support a straight 8s 1-in-3 system to replace the currently 1-in-2 watch system, the 8-on, 8-off, 4-on, 4-off system described in Paul *et al.* [2] while not optimal, would be a significant improvement over the current 7-on, 7-off, 5-on 5-off 1-in-2 watch system.

The current engineering watch periods are based on 7 work periods which have two 2-hour dog watches which ensure that the ship's engineering personnel work different hours from one day to the next. From a circadian/fatigue management perspective, this approach is counter-productive in that sailors do not get used to working the same hours each day and thus cannot adapt to their work hours from a circadian rhythm point of view. Again, see Paul *et al*. [2] for the details of this 6 work period system (0000-0400h, 0400-0800h, 0800-1200h, 1200h-1600h, 1600-2000h, 2000-0000h) where each engineering sailor would work the same two 4-h work periods each day (total 8 hours/day).

6 References

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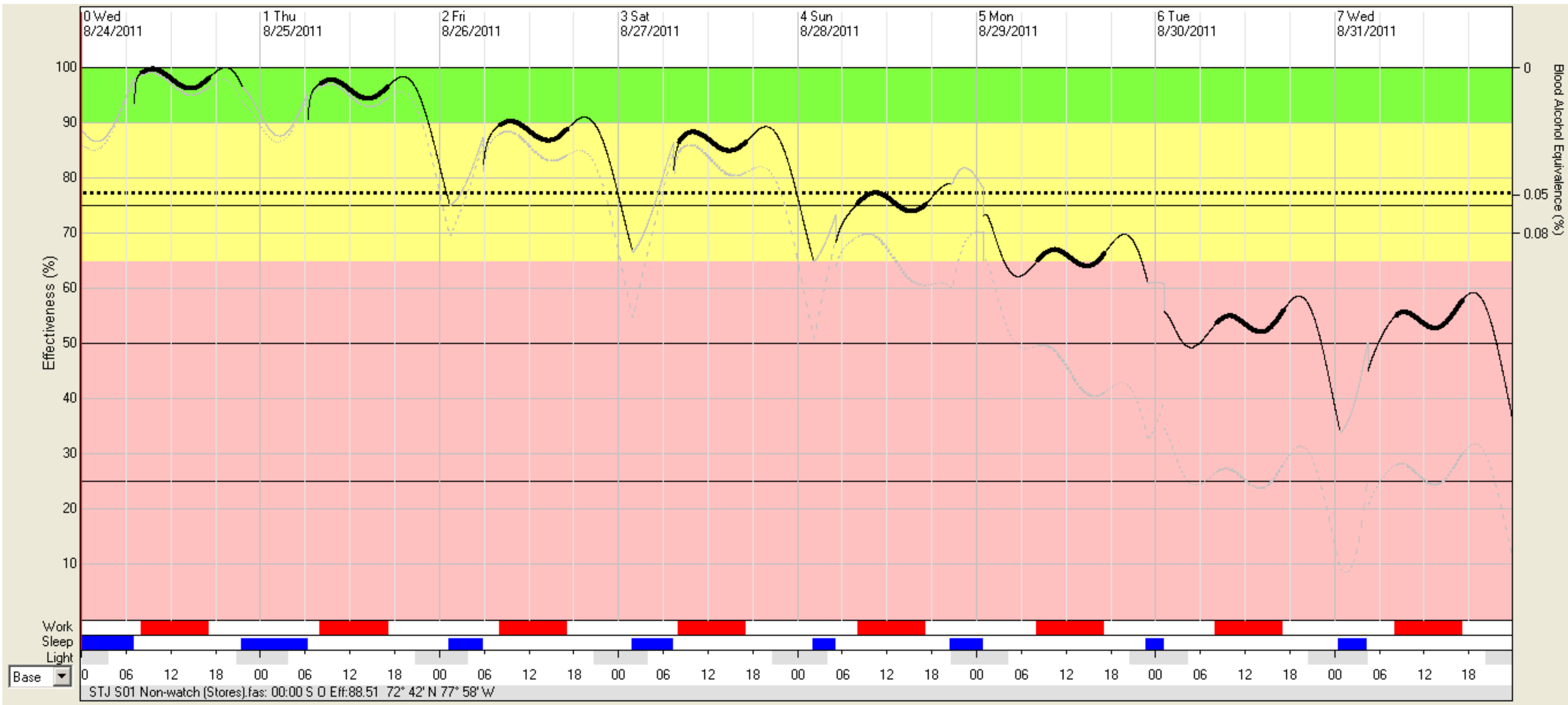
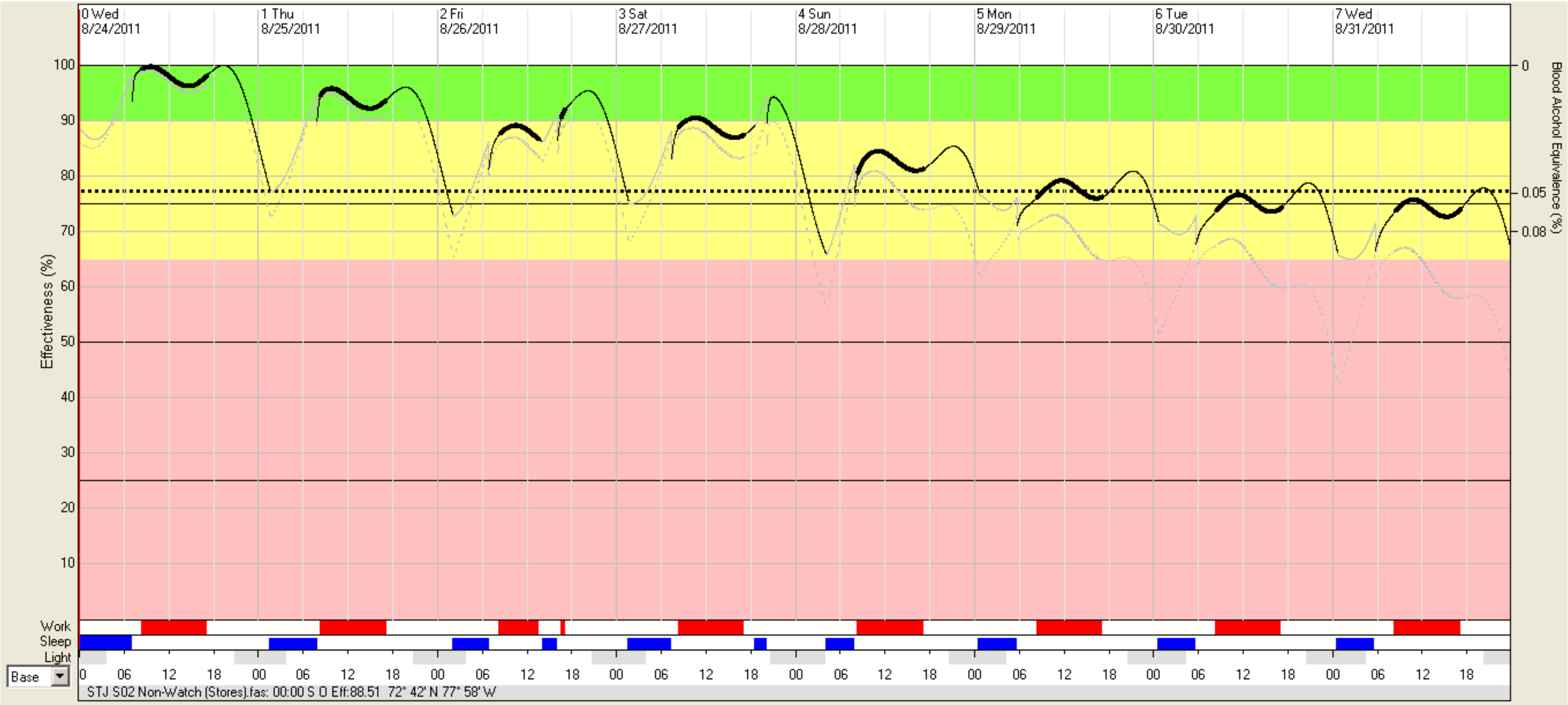
[10] Miller, J.C., Smith, M.L., McCauley, M.F. 1999. *Crew fatigue and Performance on U.S. coast Guard Cutters.* Report no. CG-D-10-99. U.S. coast Guard Research and Development Center, Groton CT,

Annex A FAST™ Models for Non-Watch-Standers

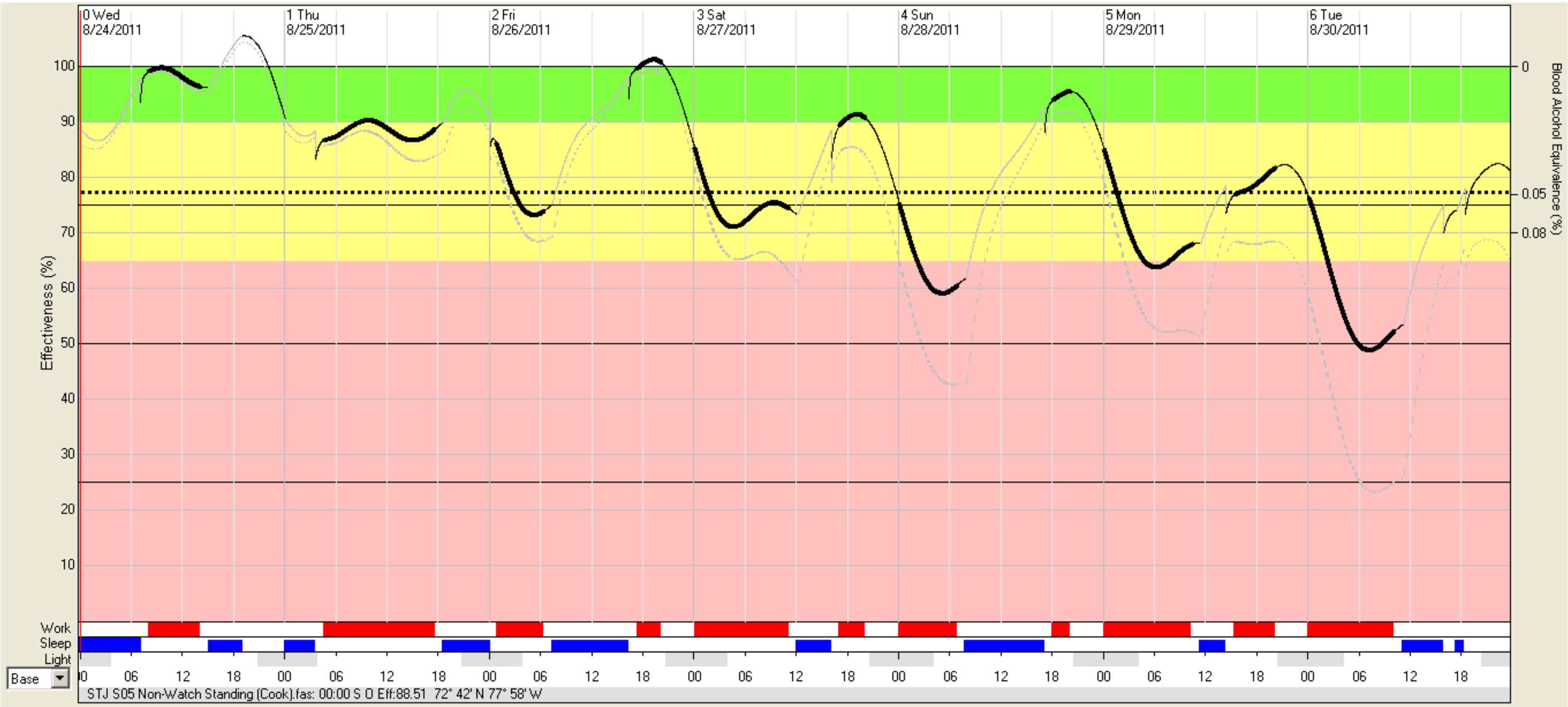
A.1 FAST™ model for Subject 1 (Storesman)



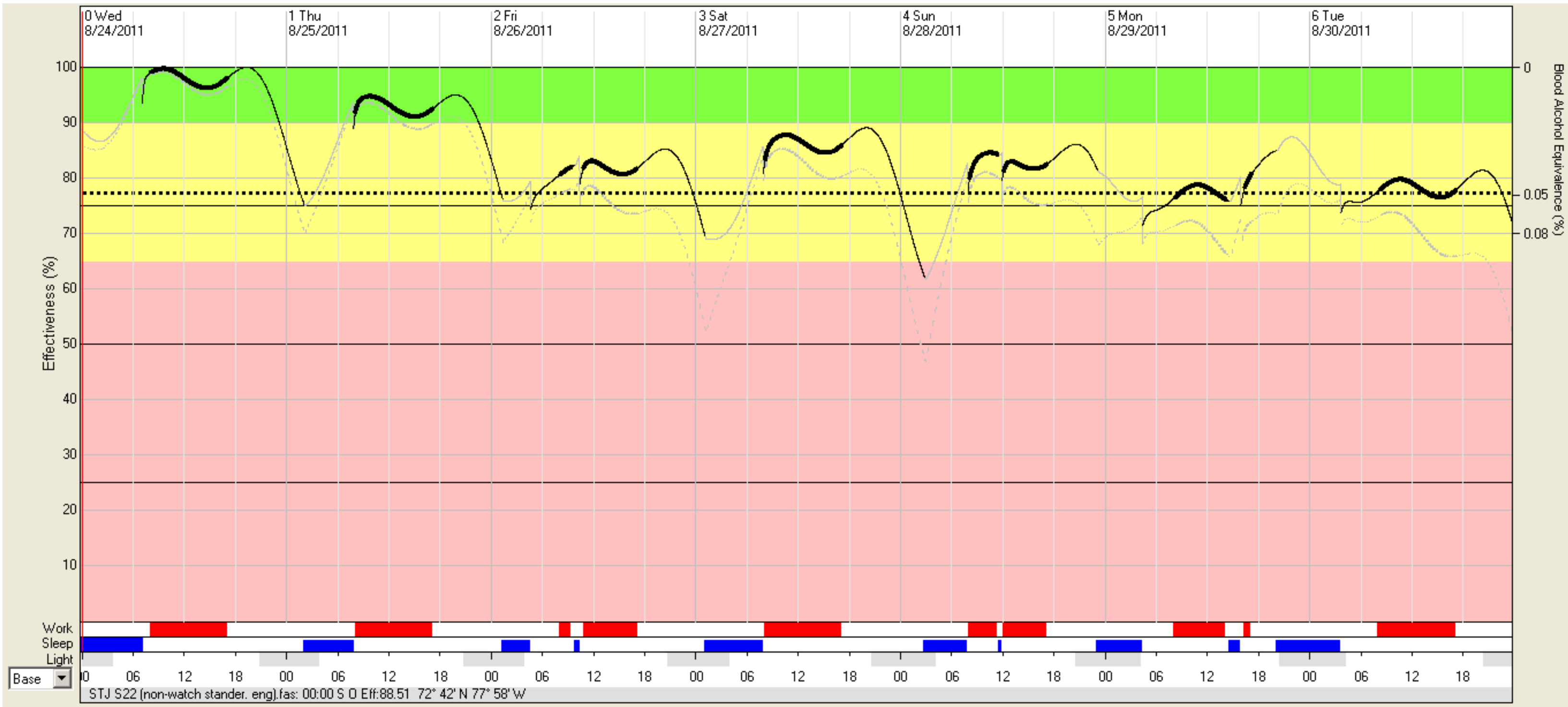
A.2 FAST™ model for Subject 2 (Storesman)



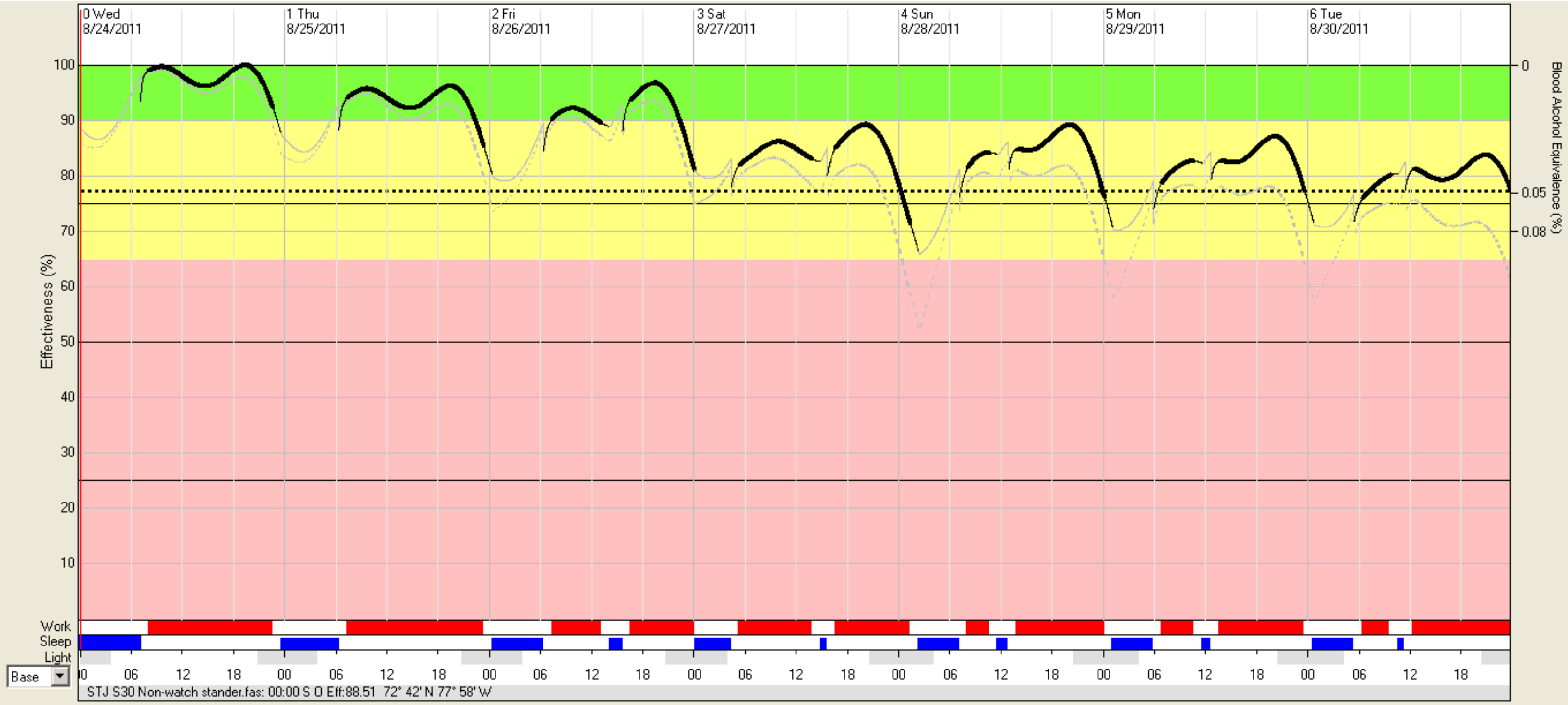
A.3 FAST™ model for subject 5 (Cook)



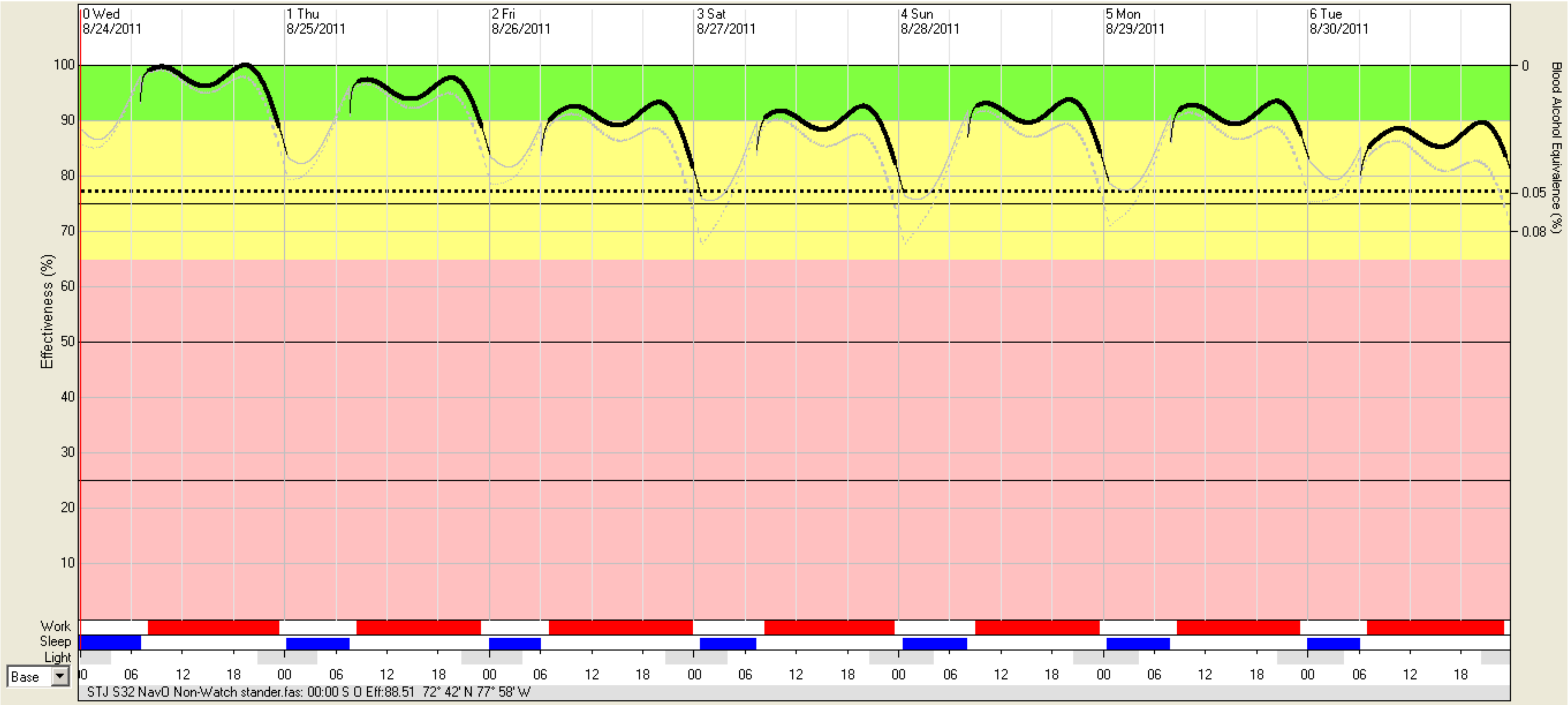
A.4 FAST™ model for Subject 22 (Engineering technician)



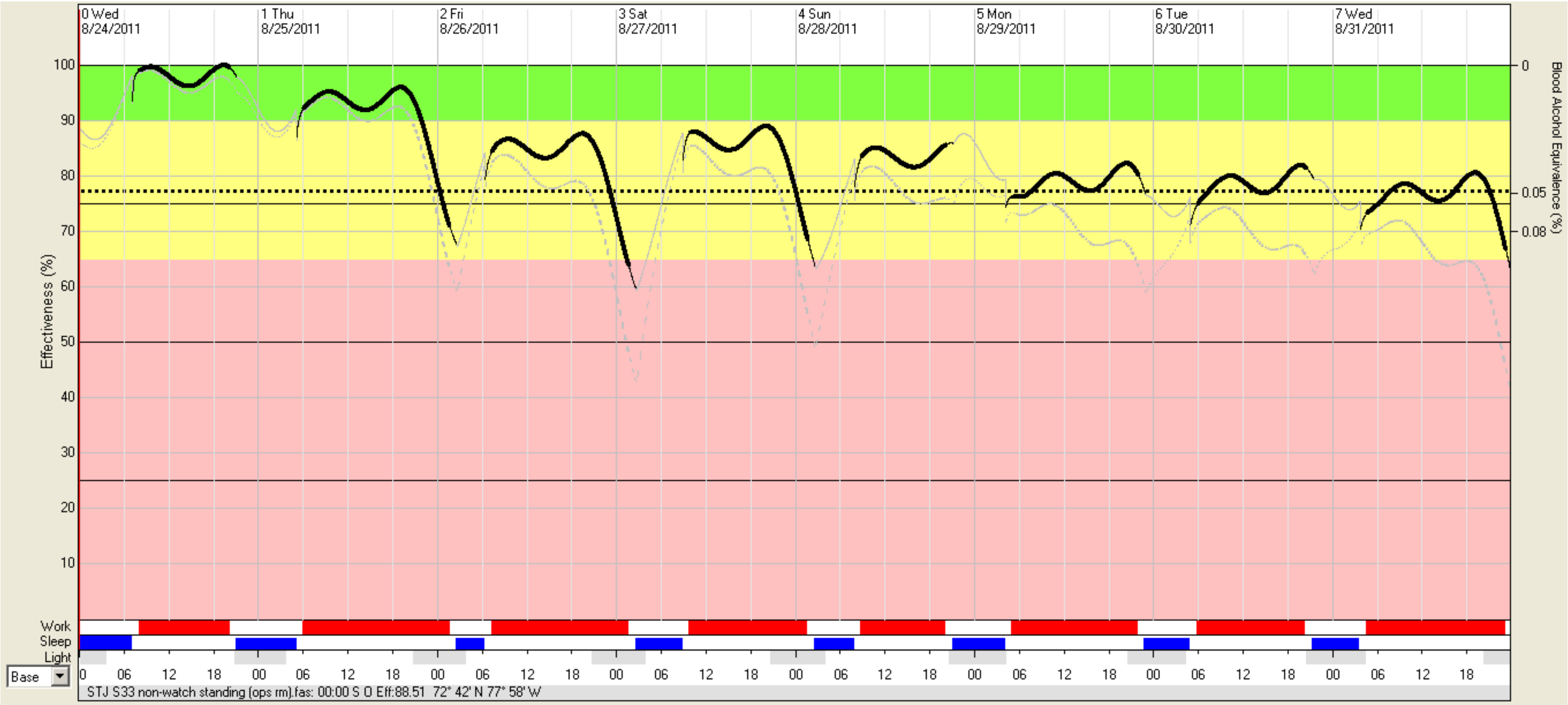
A.5 Fast™ model for Subject 30 (Combat Officer)



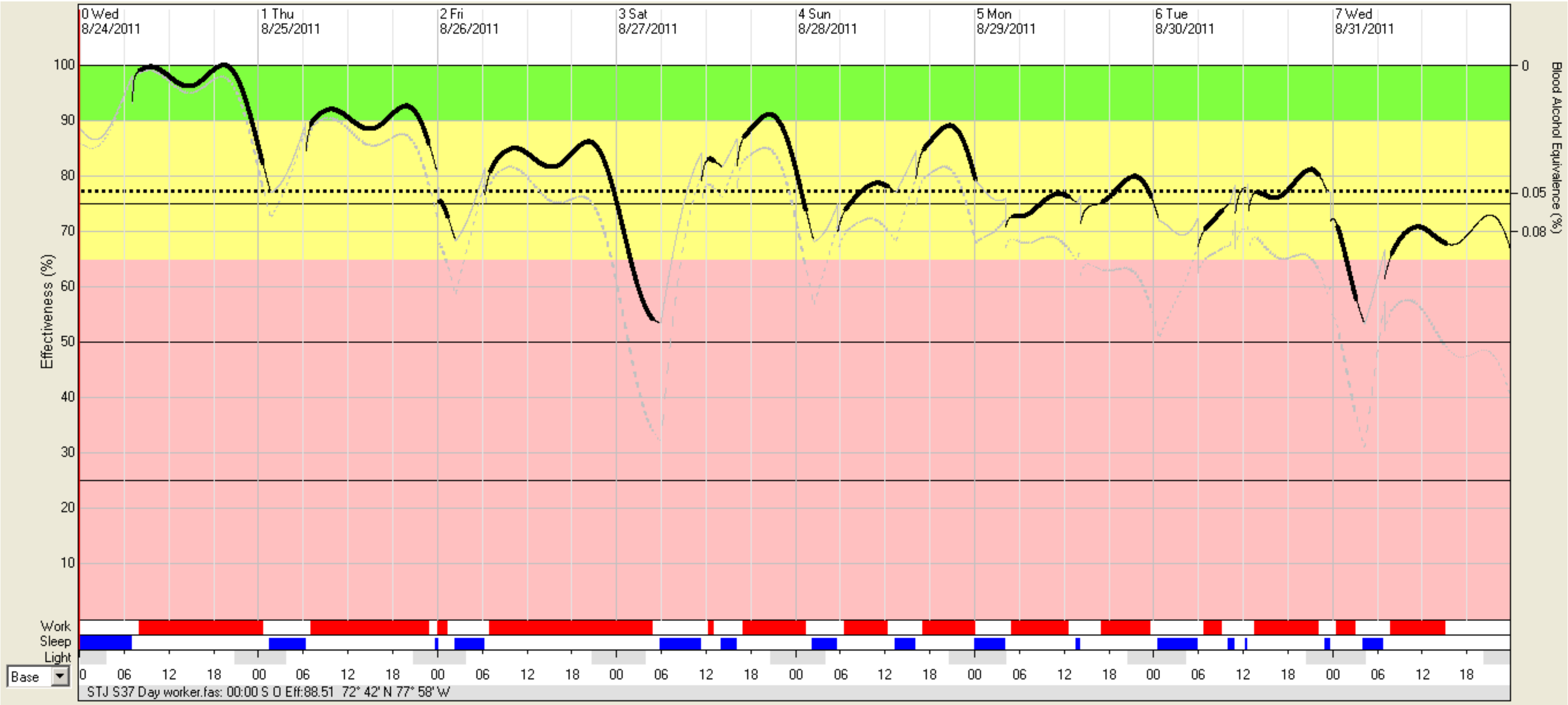
A.6 FAST™ model for Subject 32 (Navigation Officer)



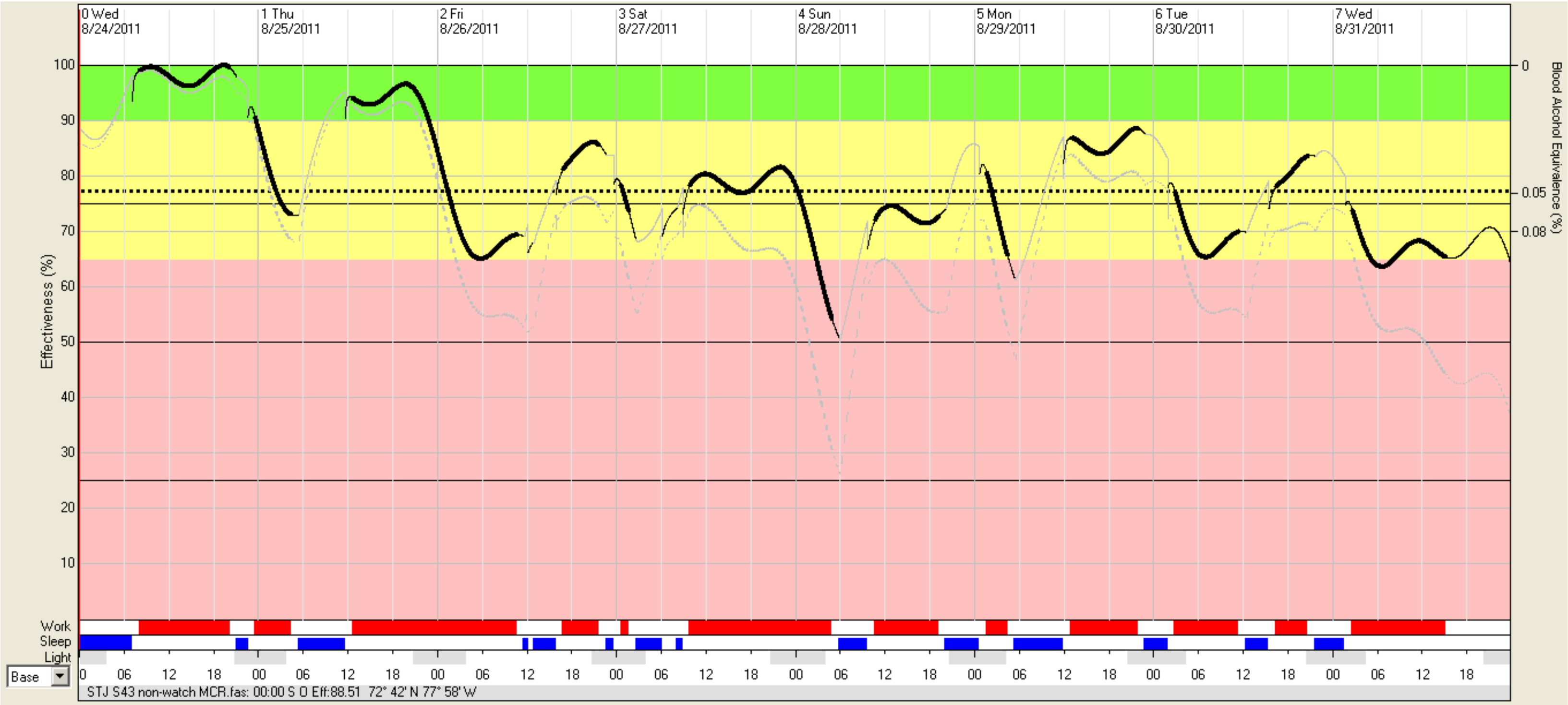
A.7 FAST™ model for Subject 33 (Operations Room Technician)



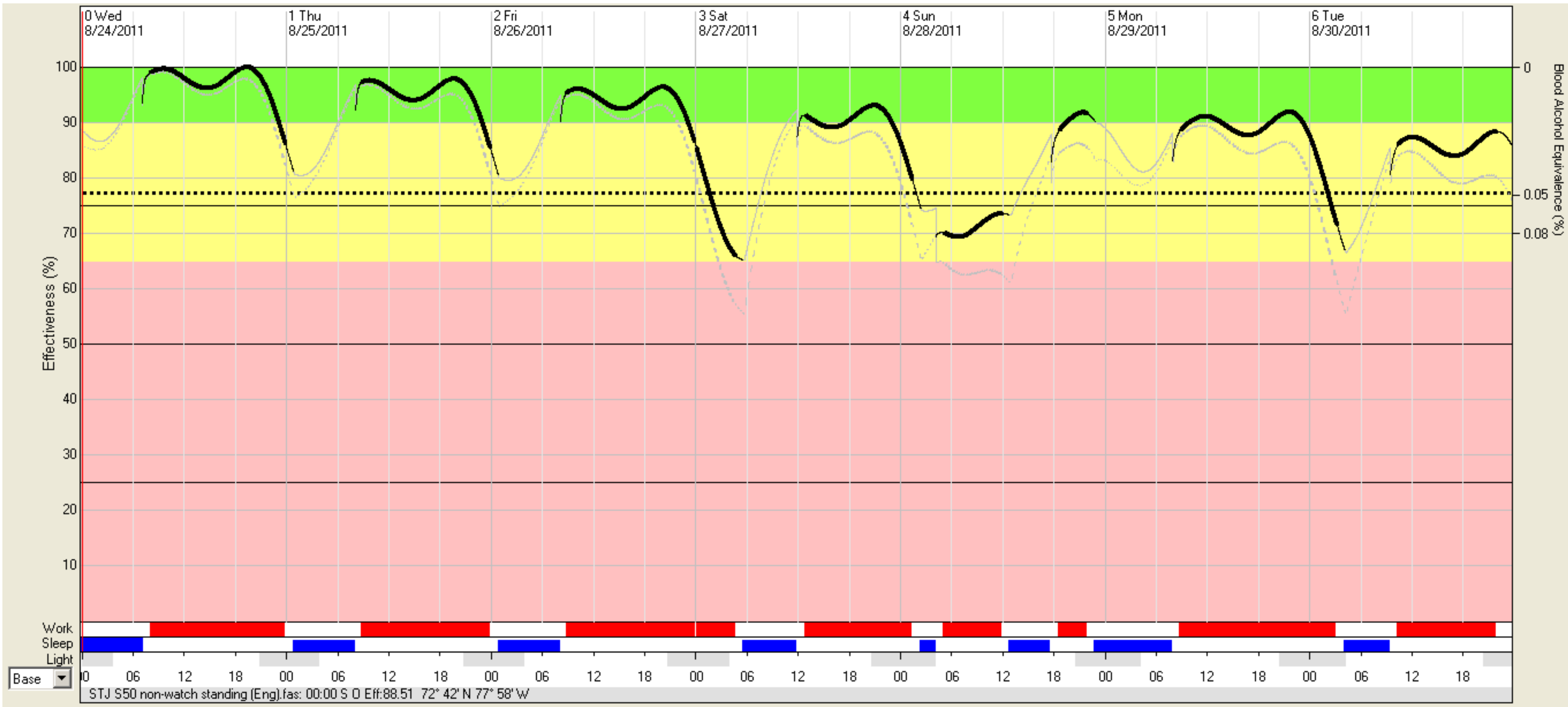
A.8 FAST™ model for subject 37 (Clerk)



A.9 FAST™ model for Subject 43 (Engineering technician)

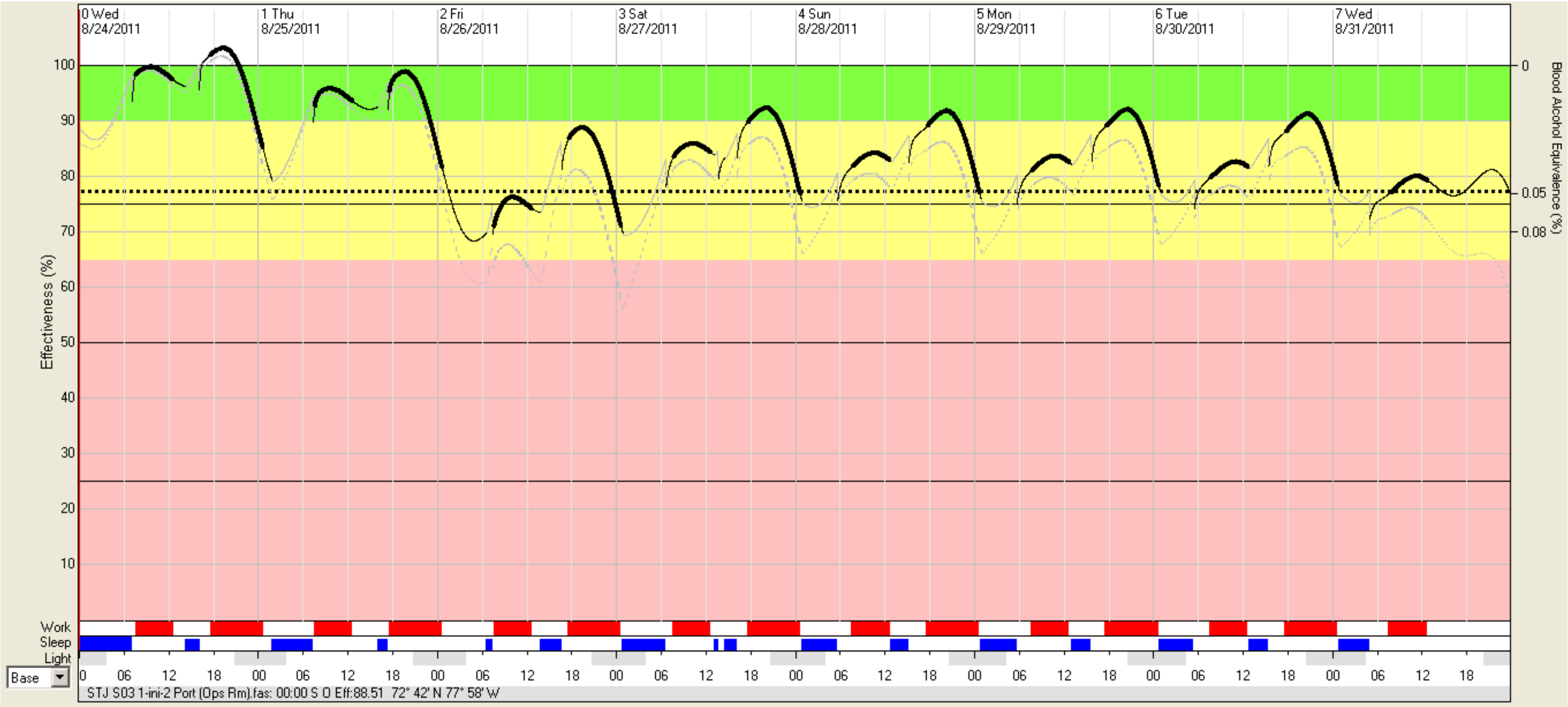


A.10 FAST^{TM} model for Subject 50 (Engineering technician)

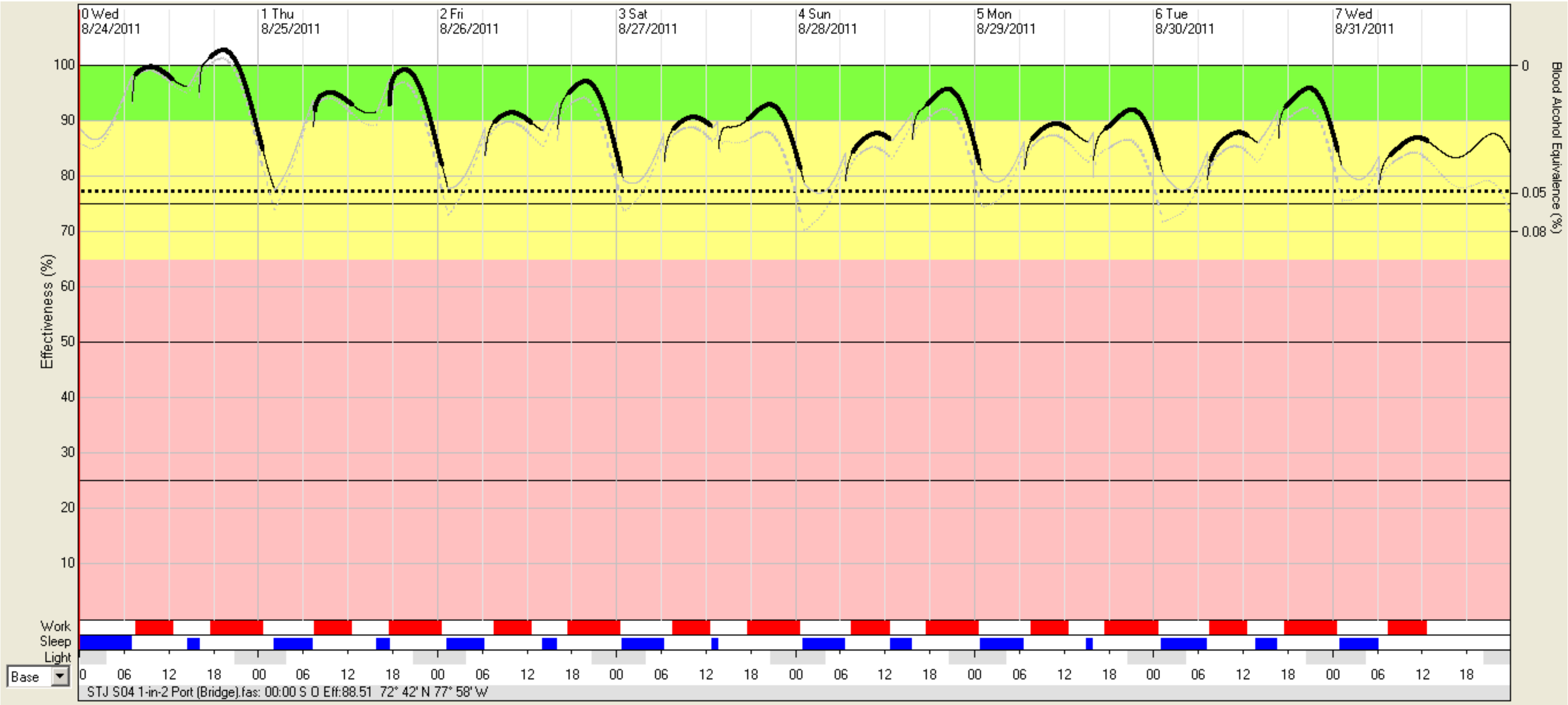


Annex B FAST™ Models for 1-in-2 Port (Front) Watch Standers

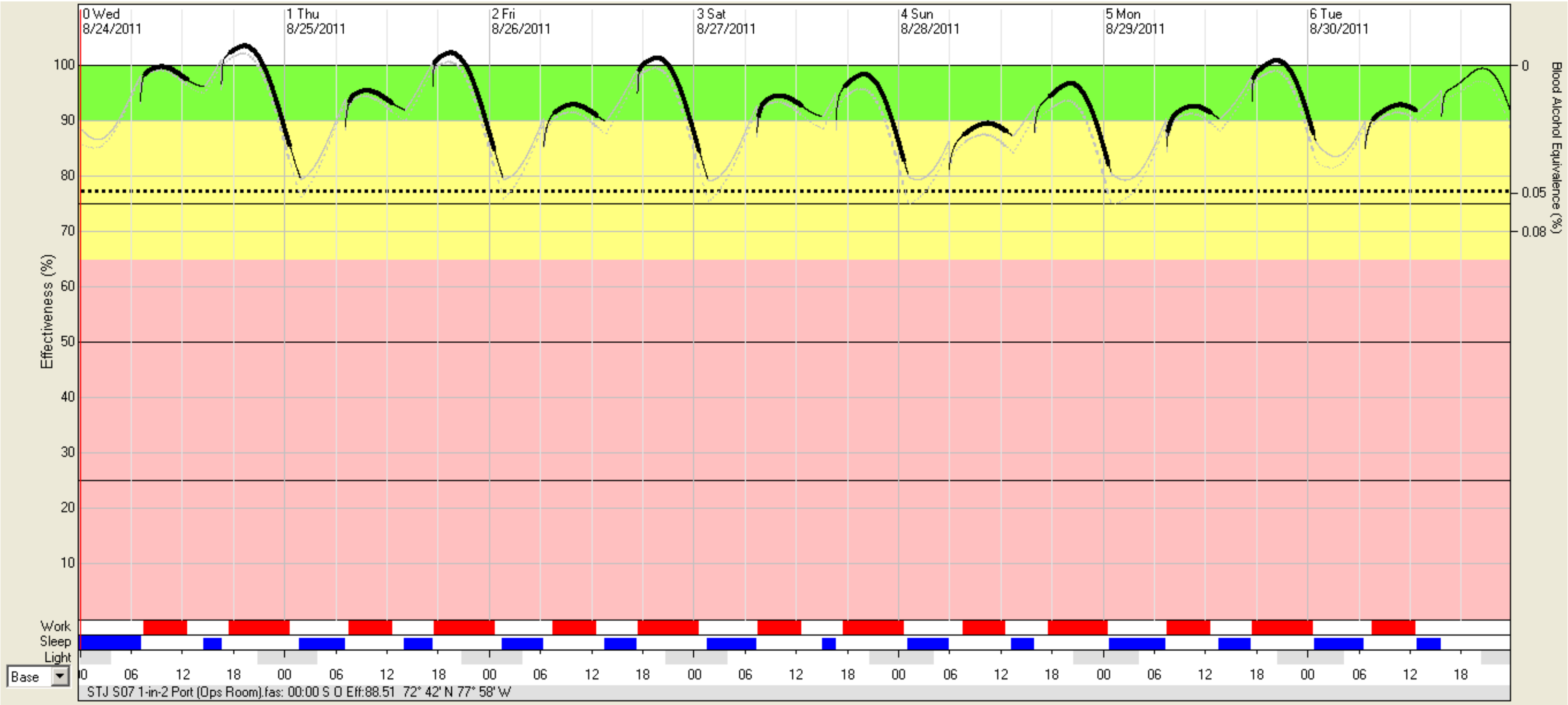
B.1 FAST™ model for Subject 3 (Operations Room Officer)



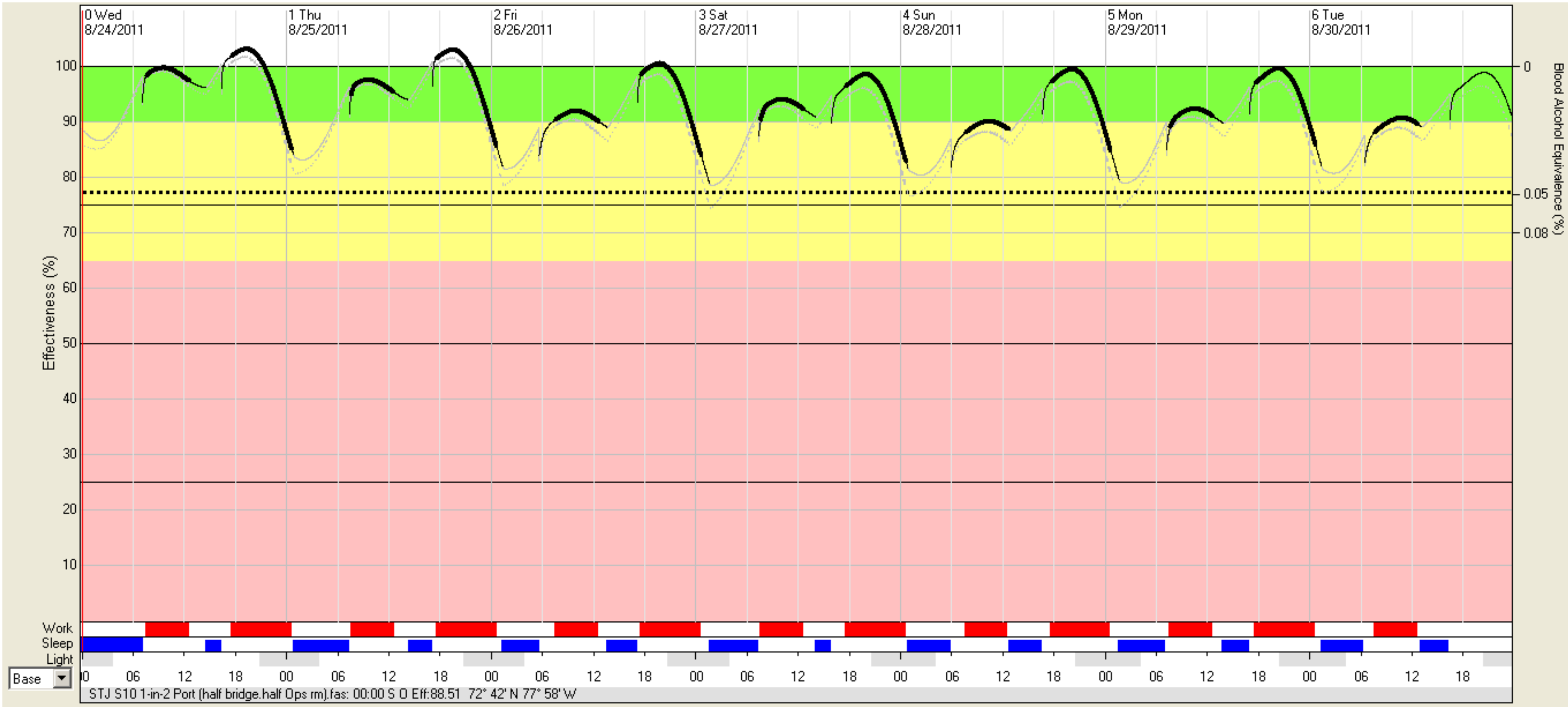
B.2 FAST^{TM} model for Subject 4 (Bridge, bosun)



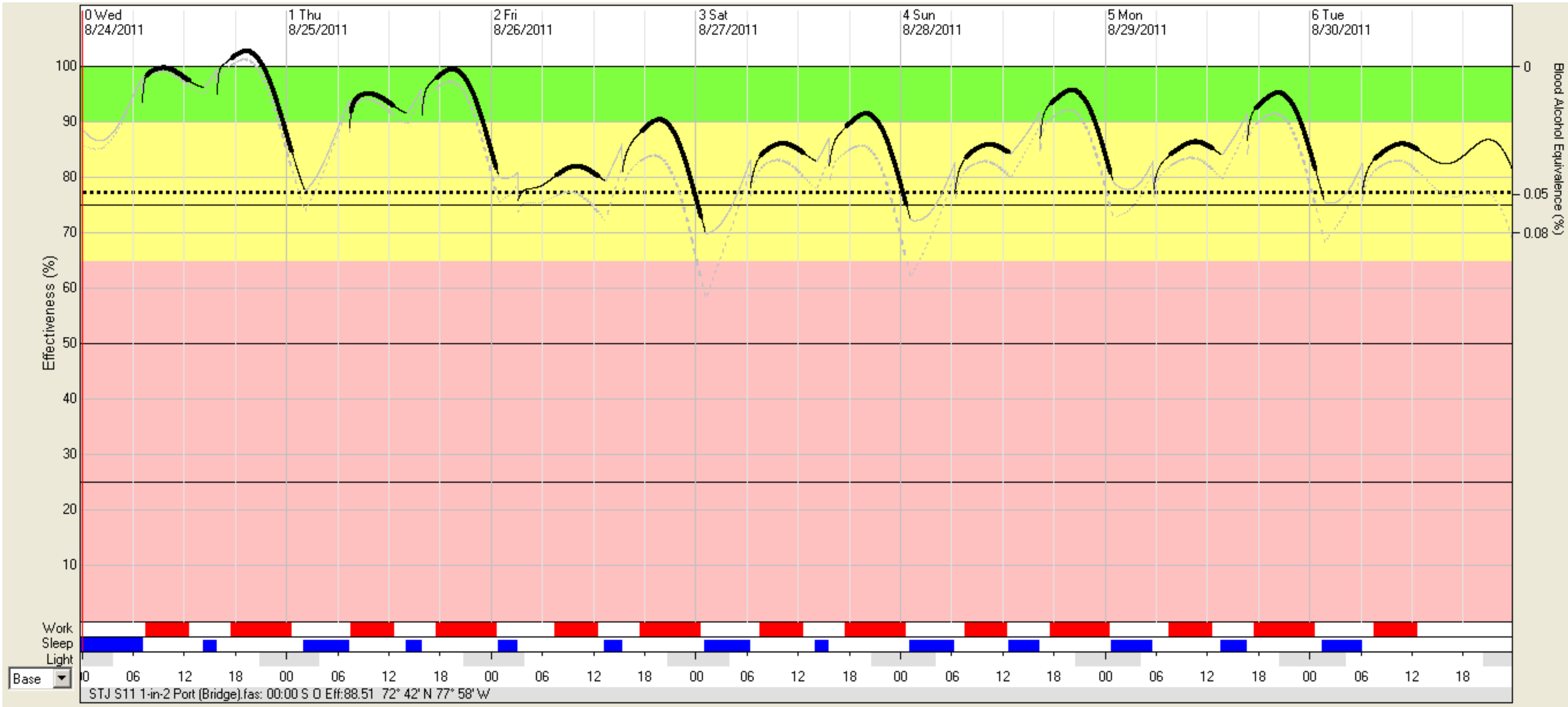
B.3 FAST™ model for Subject 7 (Operations Room, Sonar Technician)



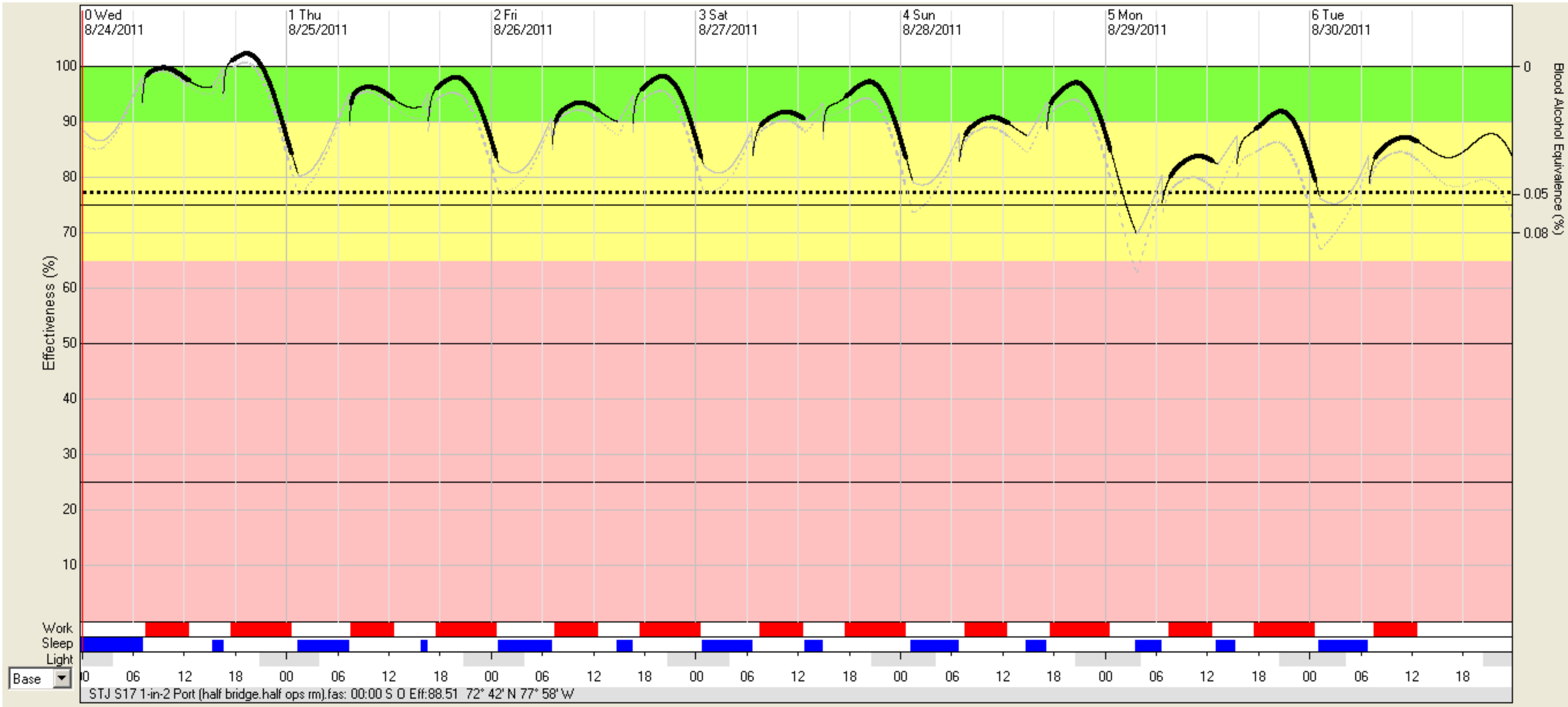
B.4 FAST™ model for Subject 10 (half-time bridge, half-time Operations Room, CommunicationsTechnician)



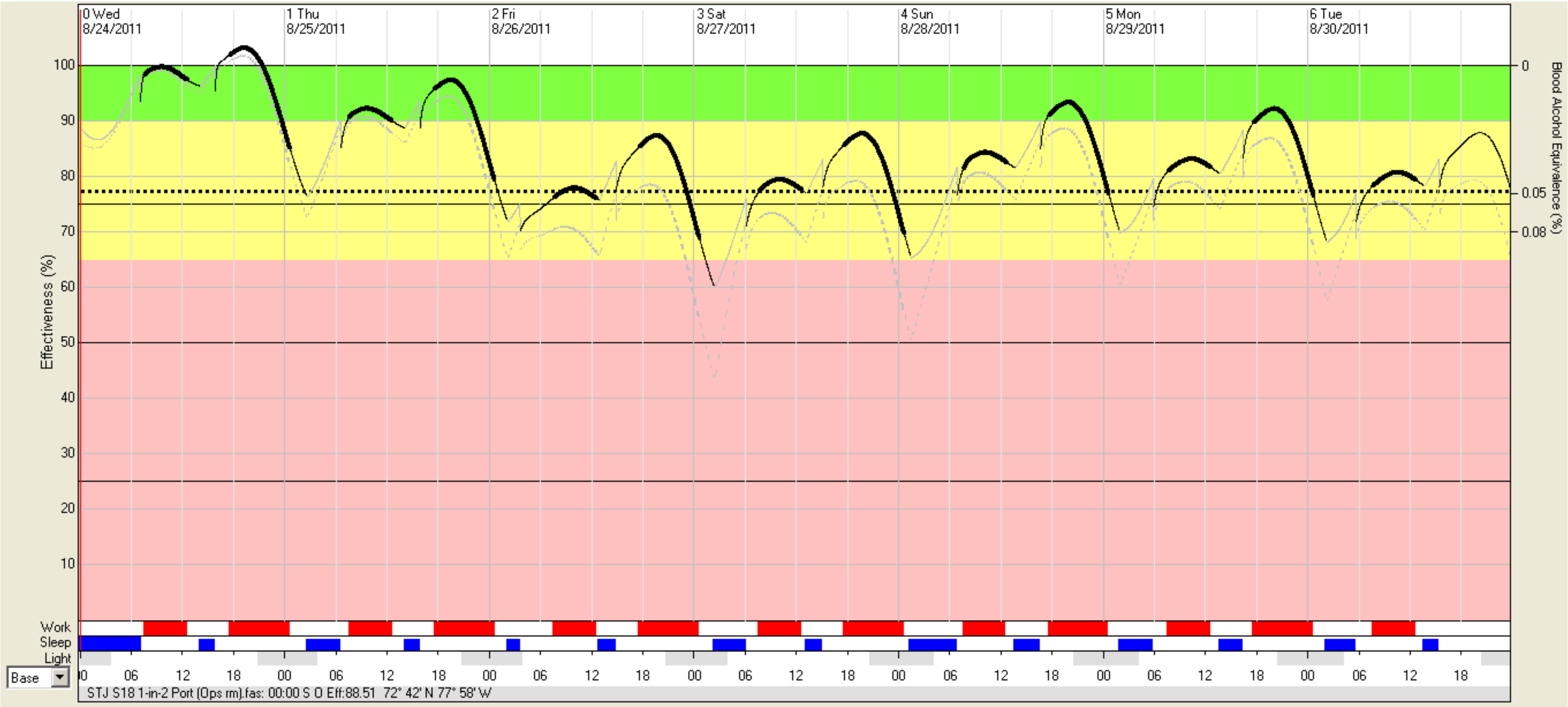
B.5 FAST™ model for Subject 11 (Bridge, Bosun)



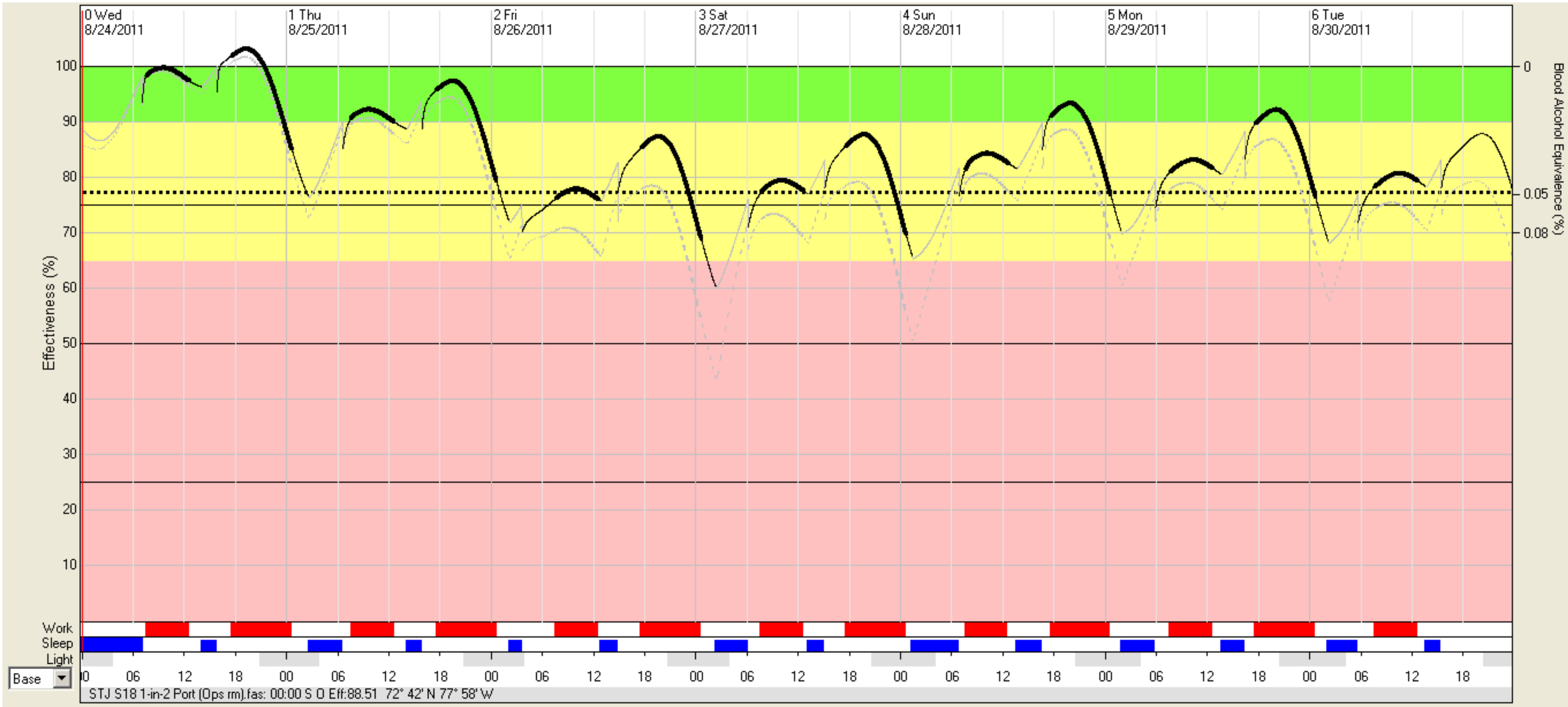
B.6 FAST™ model for Subject 17 (half-time Bridge, half-time Operations Room, Watchkeeper)



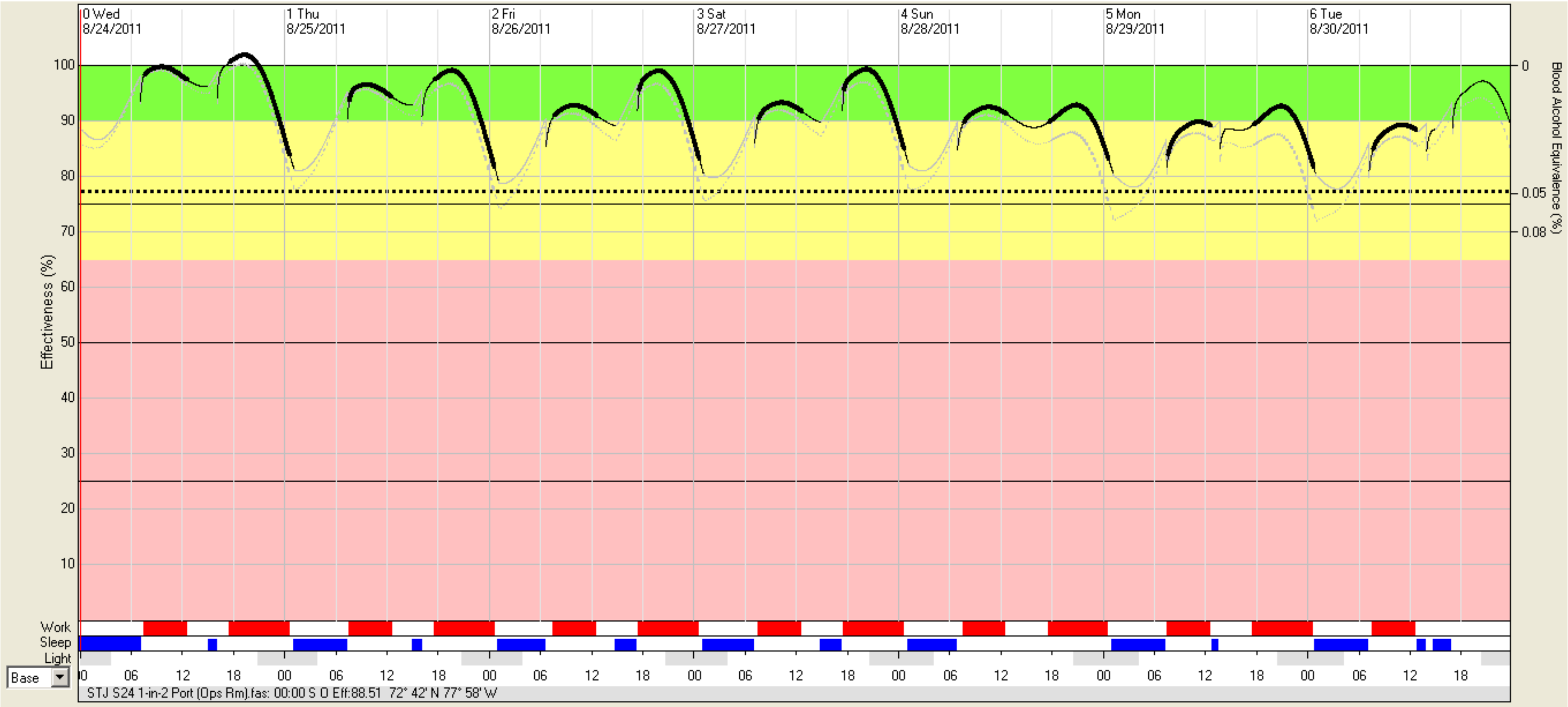
B.7 FAST™ model for Subject 18 (Communication Control Room/Bridge, Communications Technician)



B.8 FAST^{TM} model for Subject 21 (Bridge, Bosun)

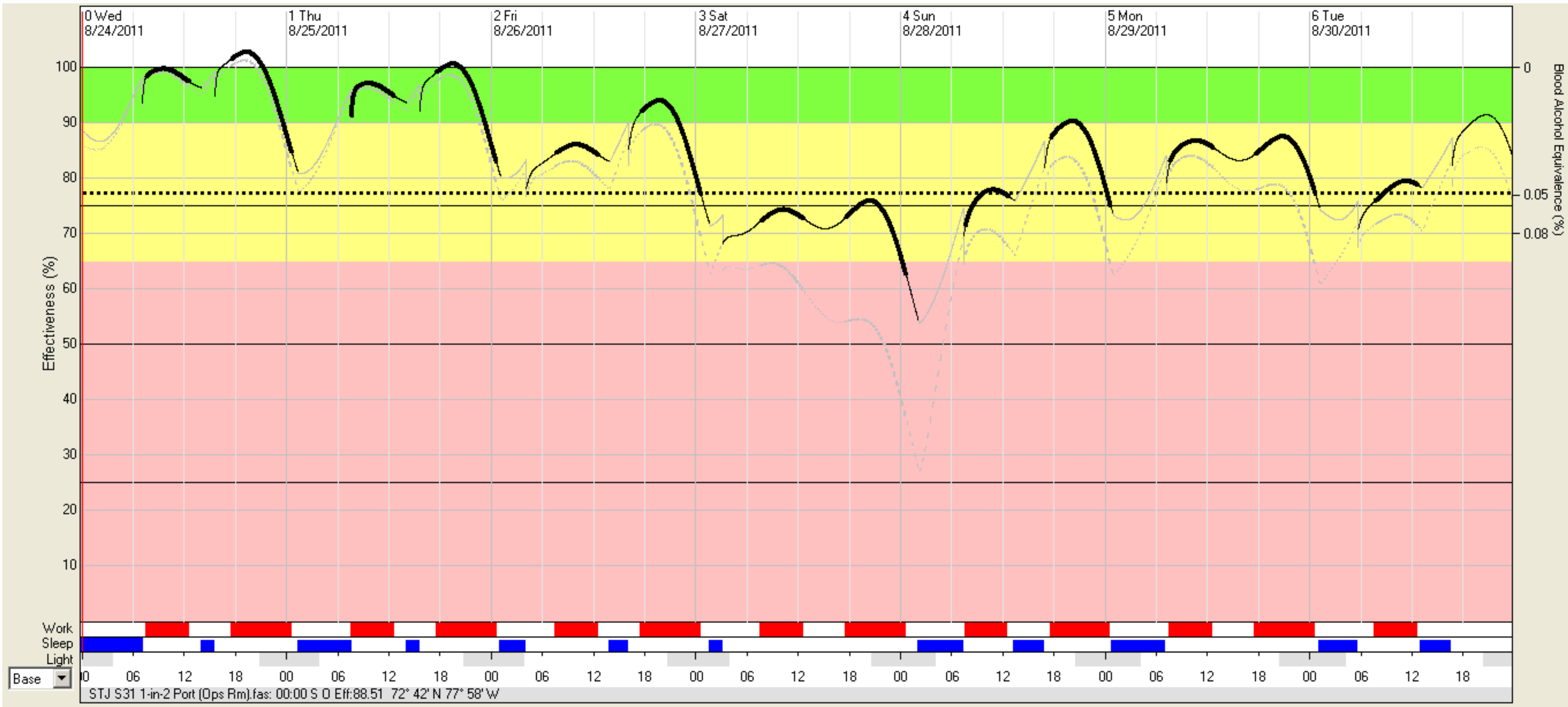


B.9 FAST™ model for Subject 24 (Operations Room, Combat Systems Engineering Technician)

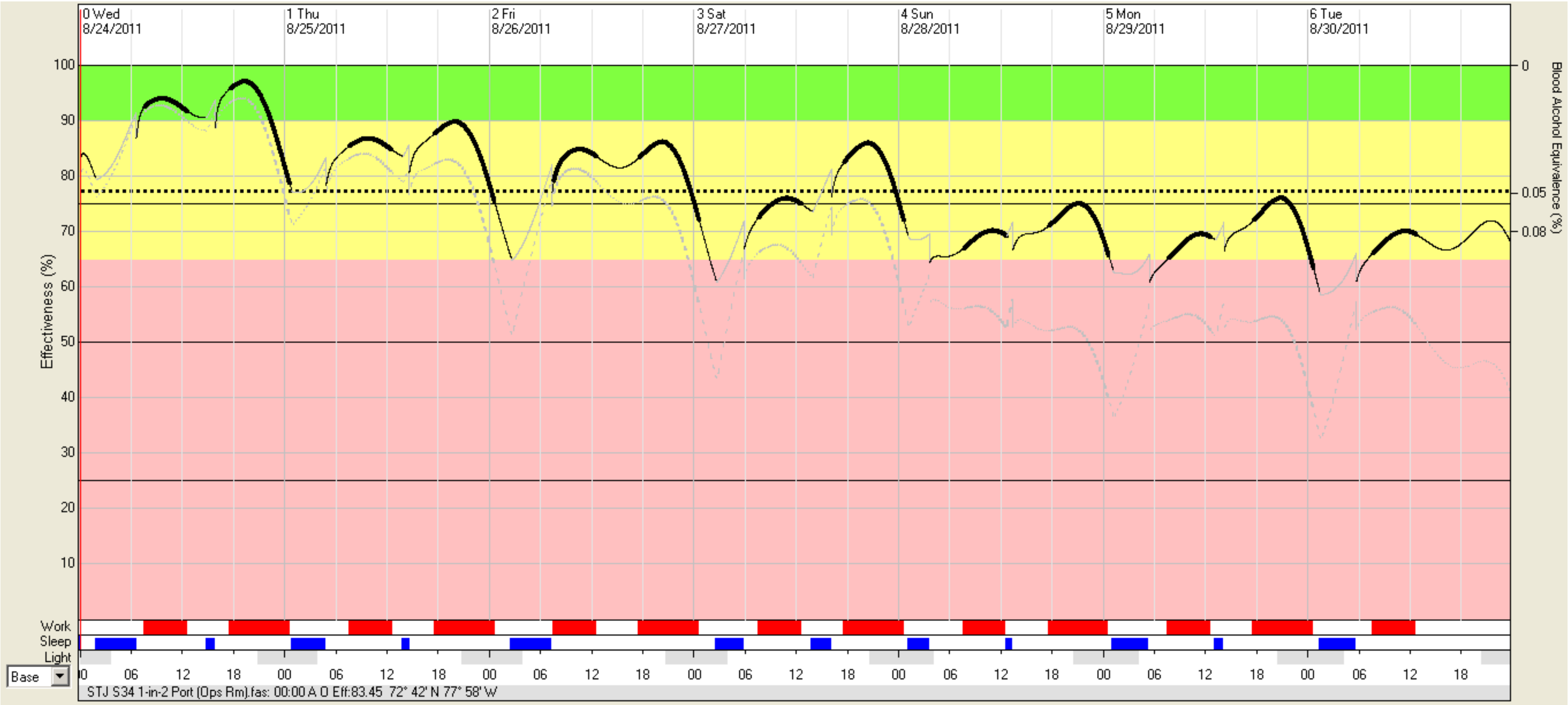


B.10 Subject 26, No FAST^{TM} model available given actigraph failure, and that self-reported sleep times do not match 1-in-2 Port (Front) watch

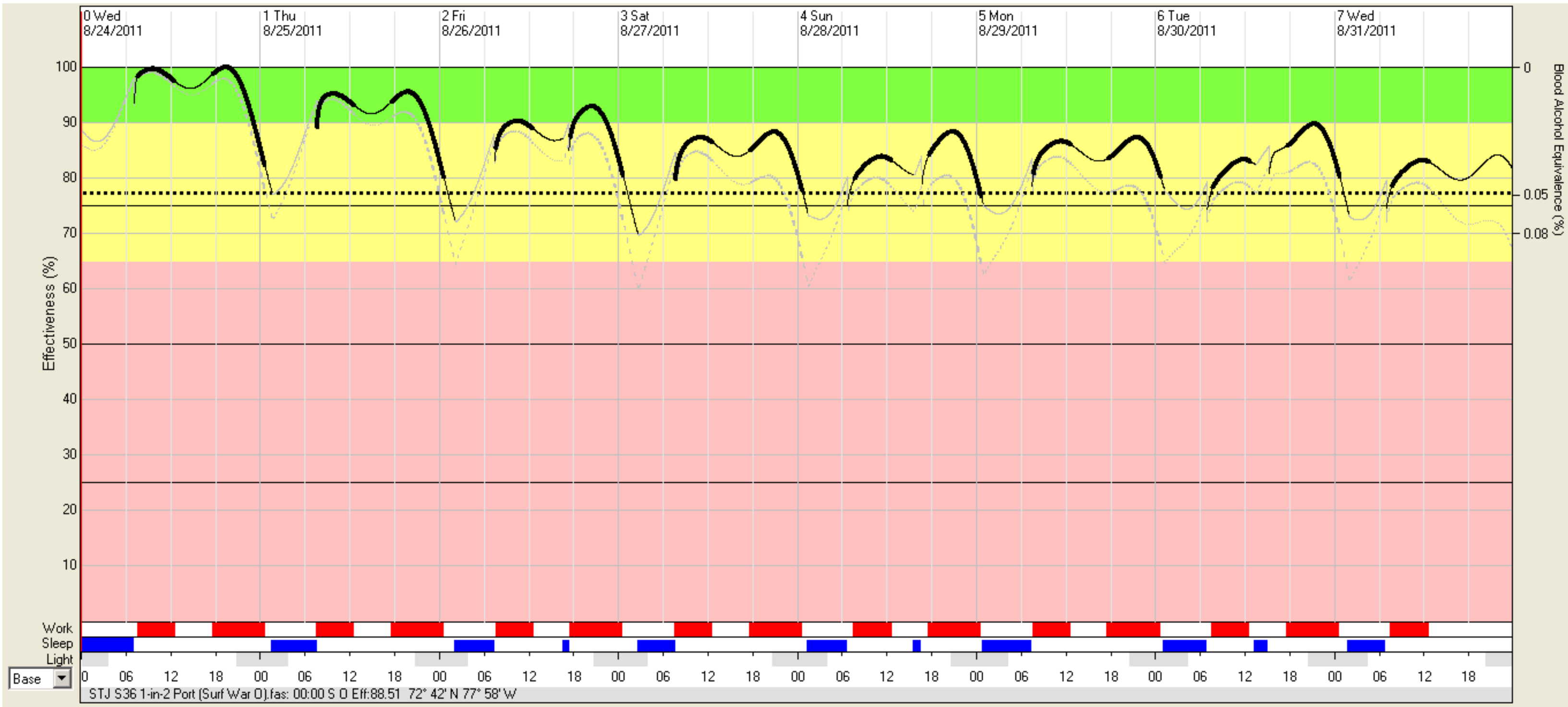
B.11 FAST™ model for Subject 31 (Operations Room, Radar Plotter, Emergency Responder, Naval Boarding Party)



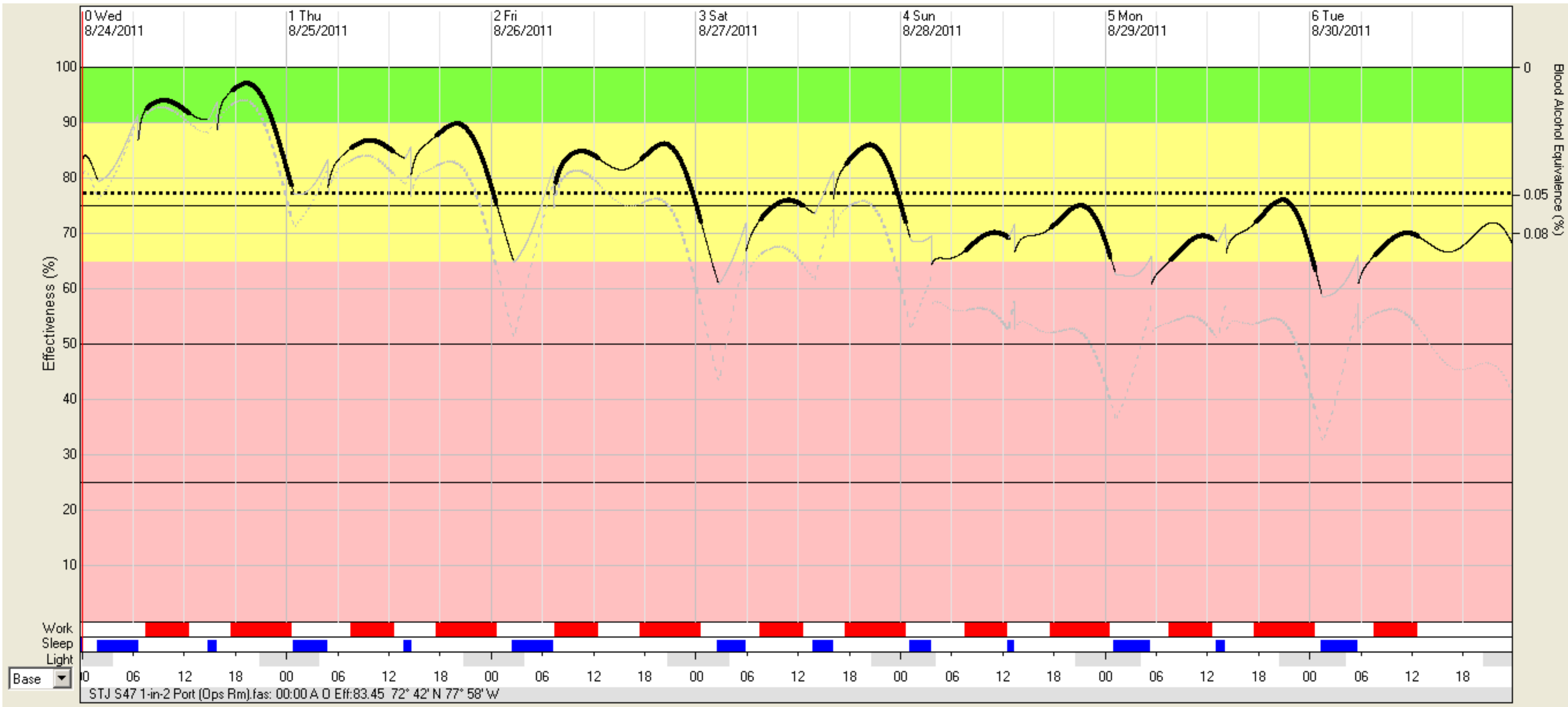
B.12 FAST™ model for Subject 34 (Operations Room, Radar Plotter, NESOP)



B.13 FAST™ model for Subject 36 (Surface Warfare Director)

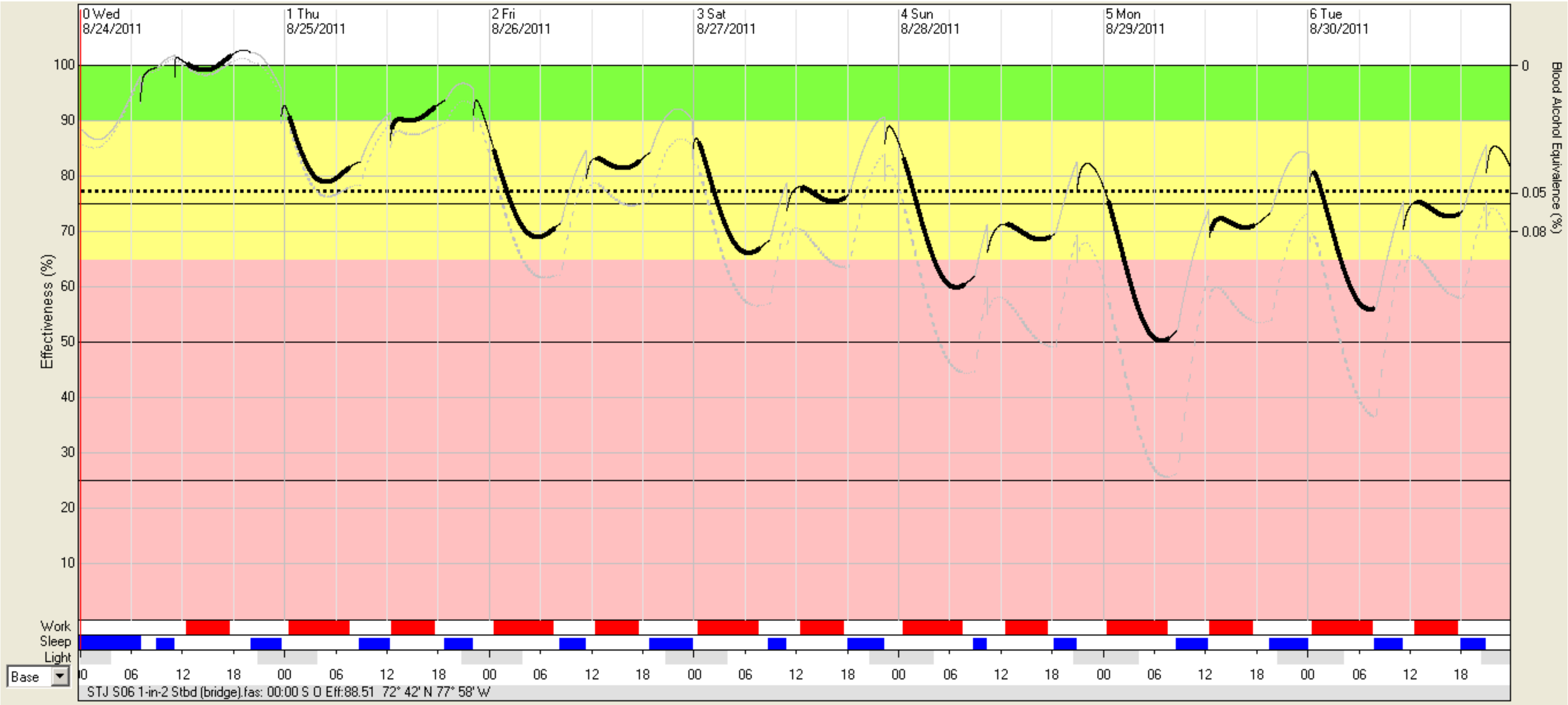


B.14 FAST™ model for Subject 47 (Operations Room, Supervisor)

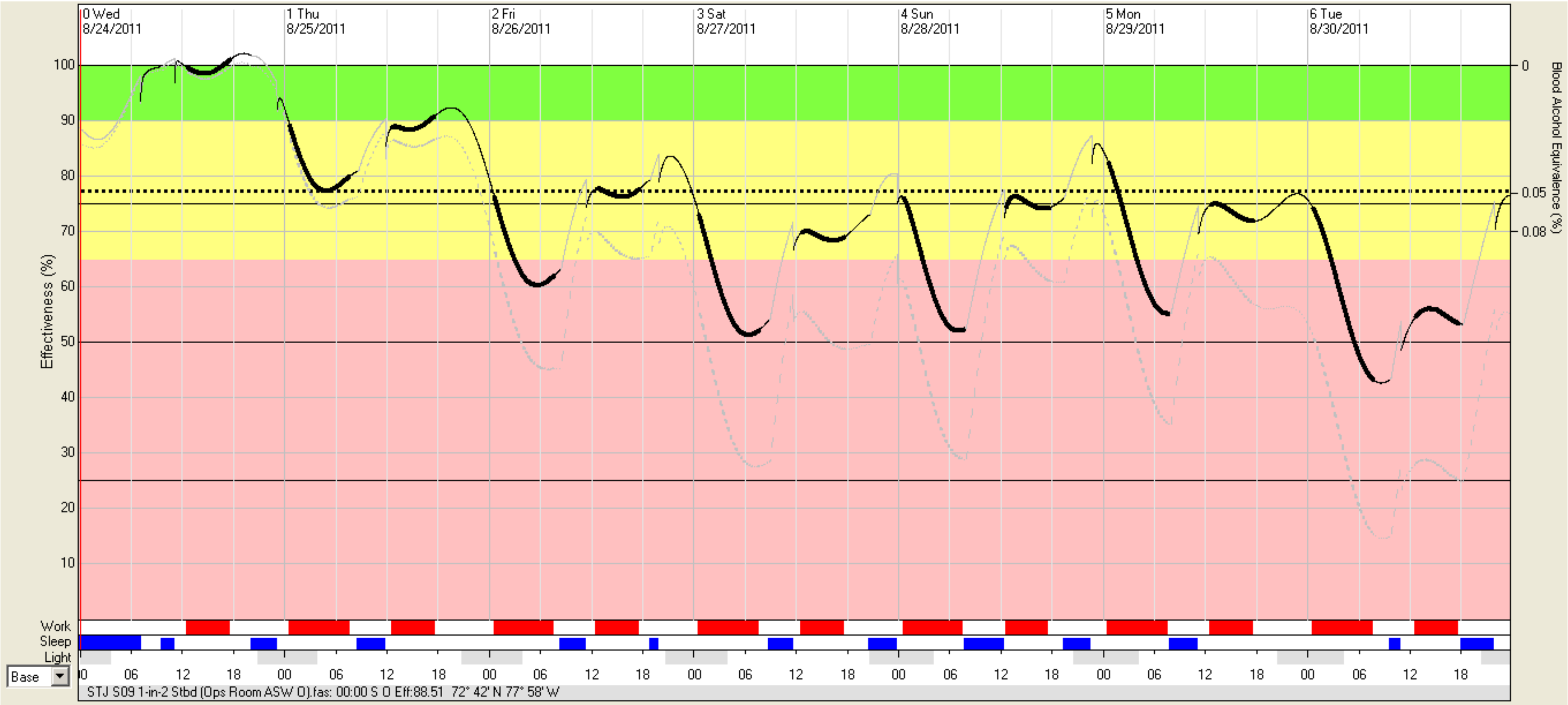


Annex C FAST™ Models for 1-in-2 Starboard (Back) Watch Standers

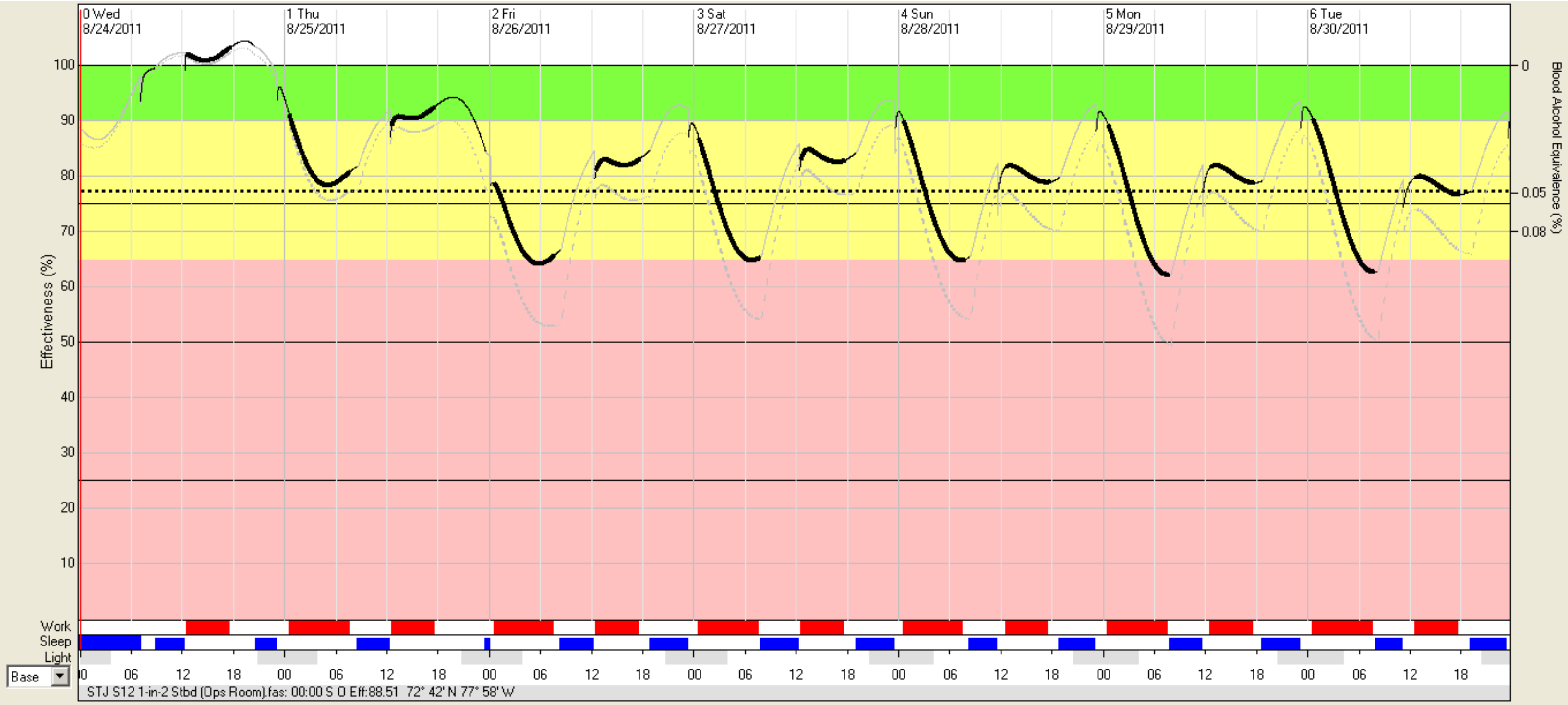
C.1 FAST™ model for Subject 6 (Bridge, Quartermaster of the Watch)



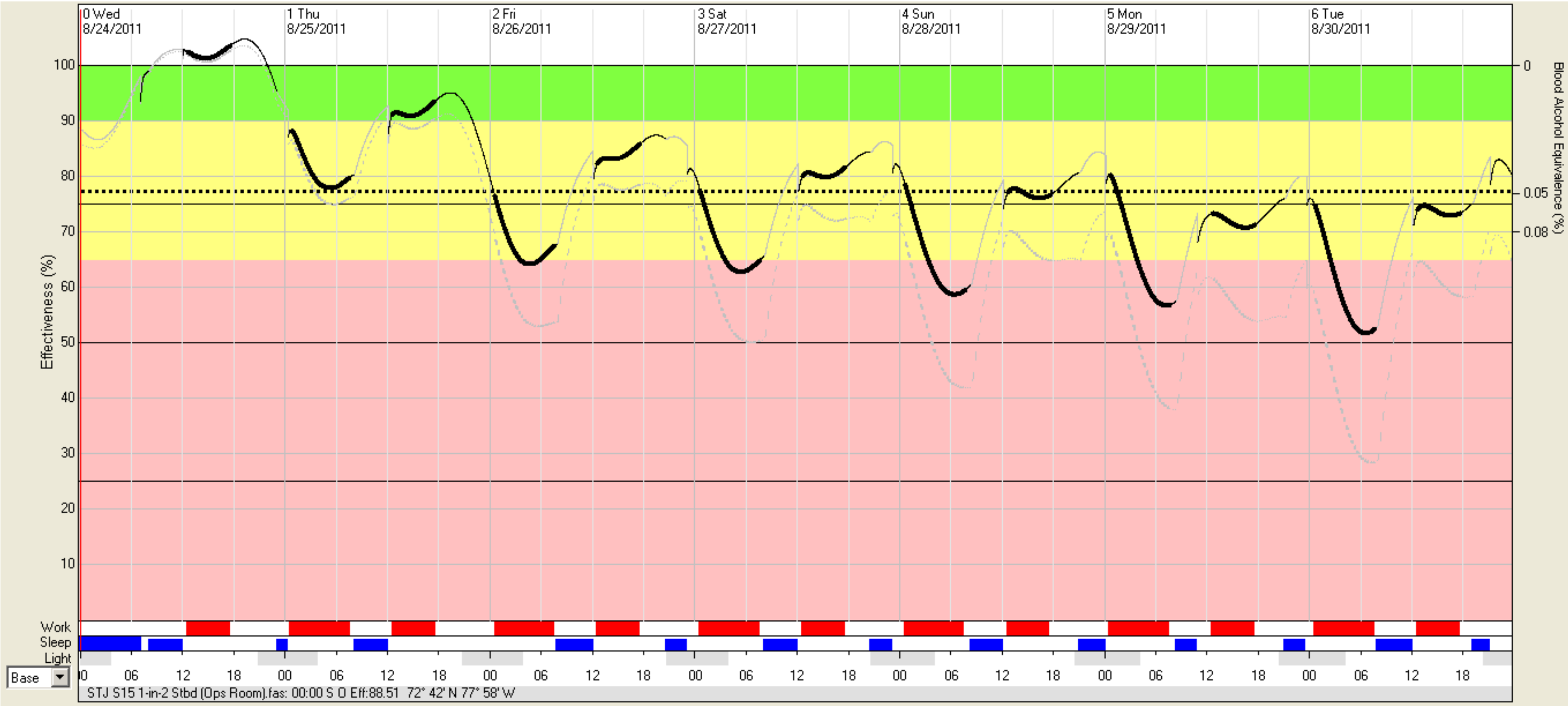
C.2 FAST™ model for Subject 9 (Operations Room, Underwater Warfare Officer)



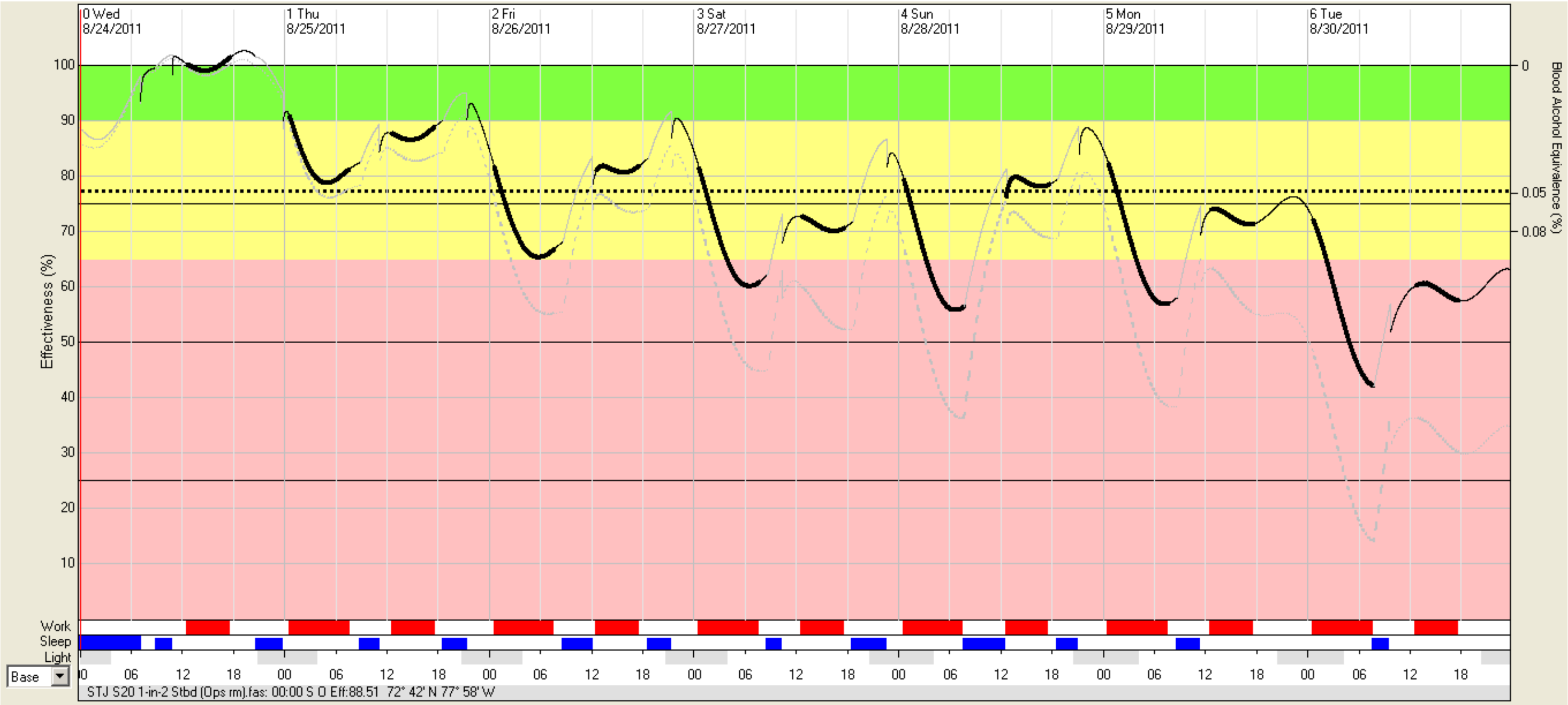
C.3 FAST^{TM} model for Subject 12 (Operations Room, NESOP)



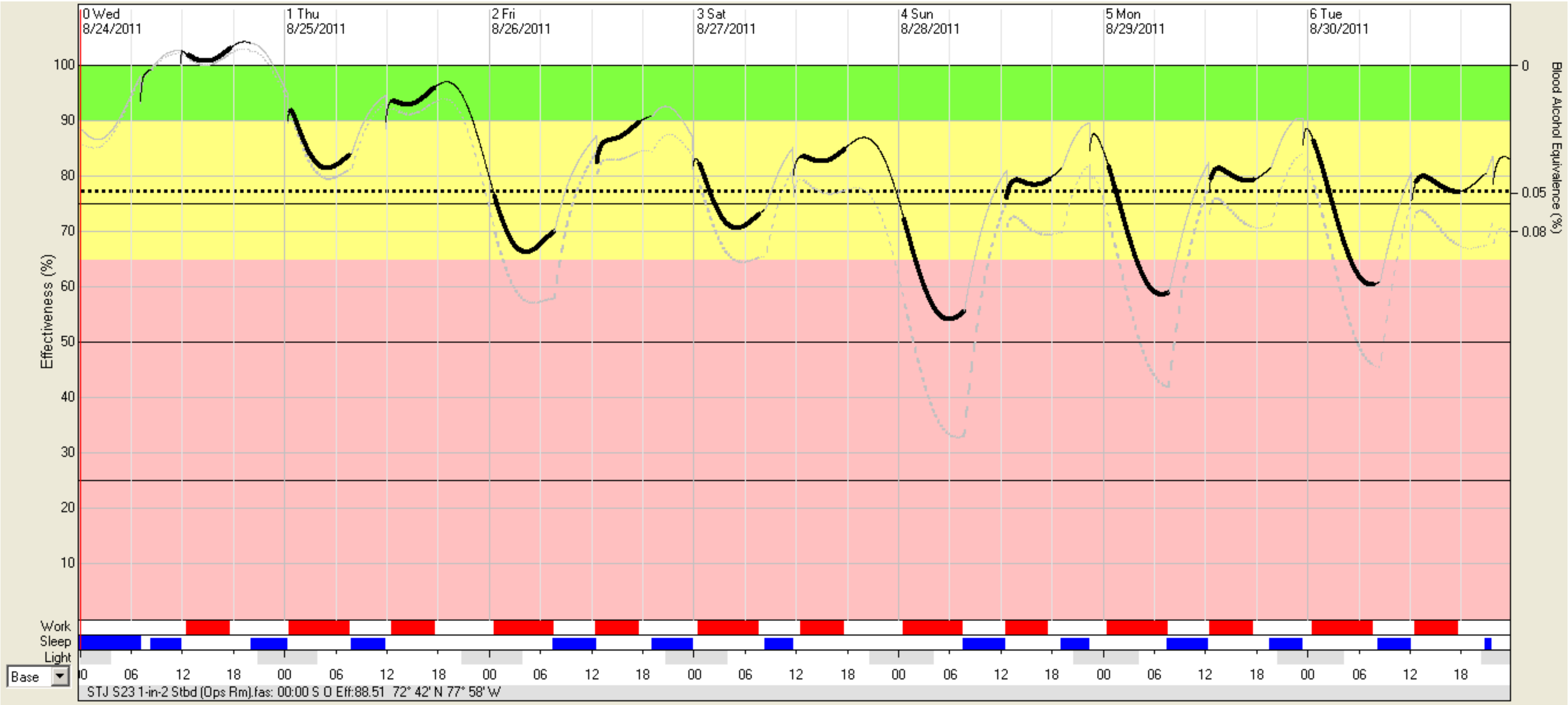
C.4 FAST™ model for Subject 15 (Operations Room, Operator)



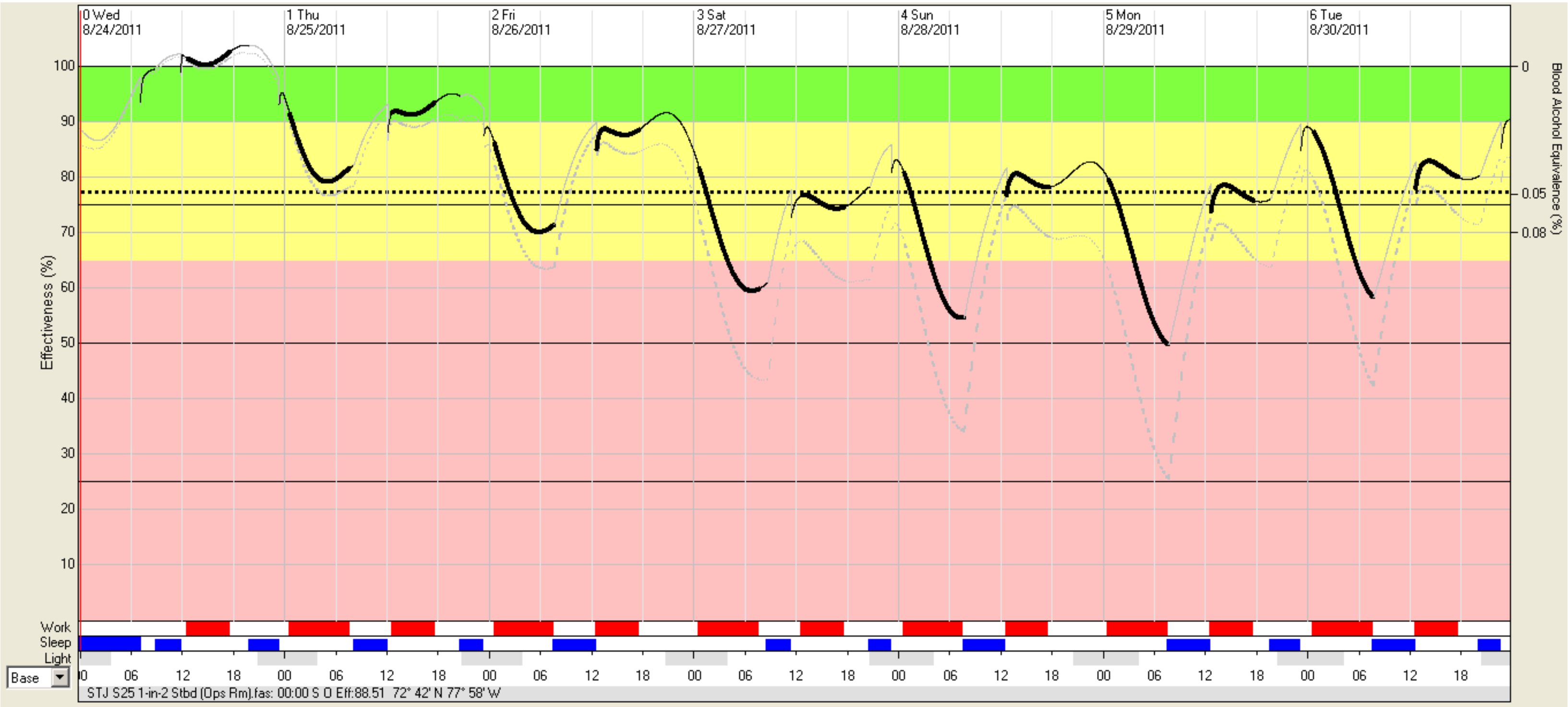
C.5 FAST™ model for Subject 20 (Operations Room, Sonar Operator, Watch Supervisor)



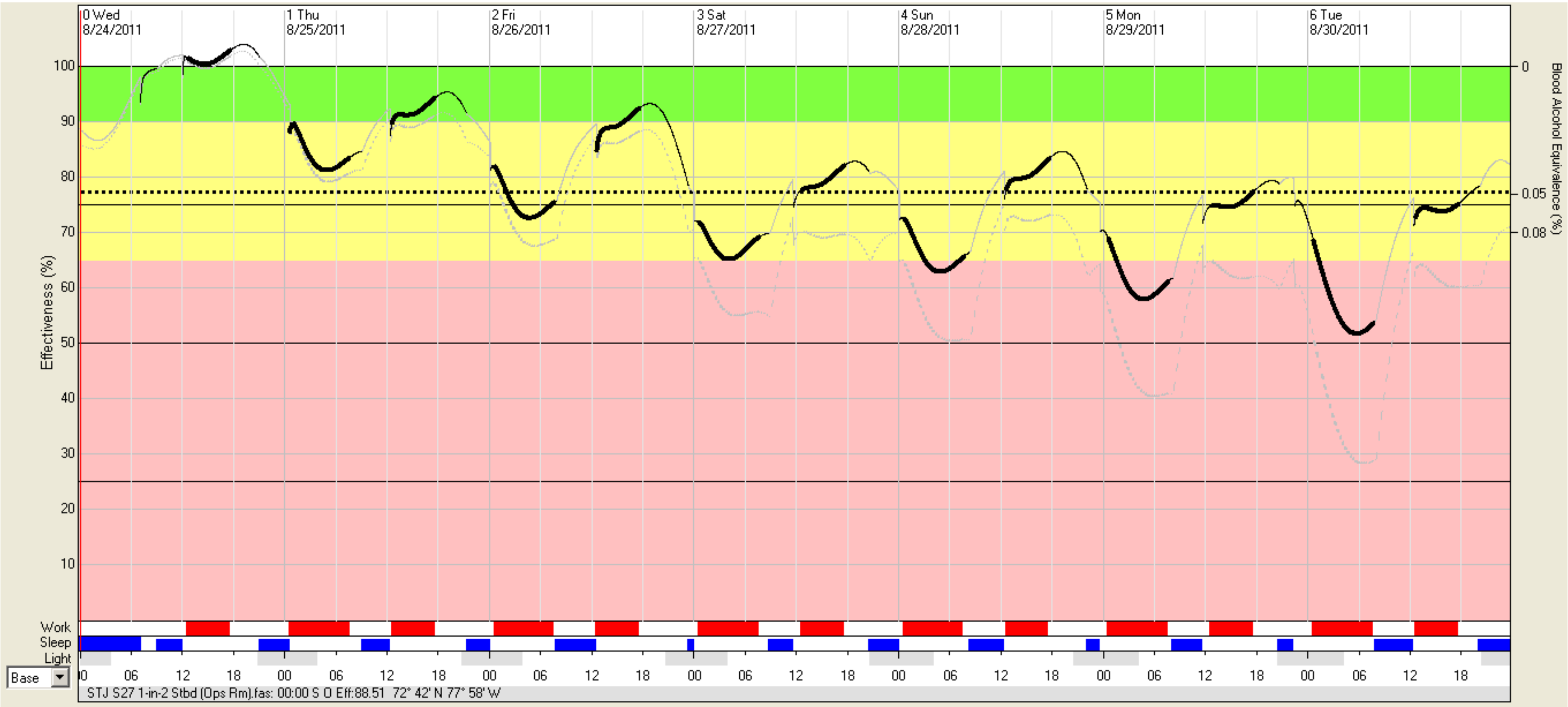
C.6 FAST[TM] model for Subject 23 (Operations Room, Naval Combat Information Operator)



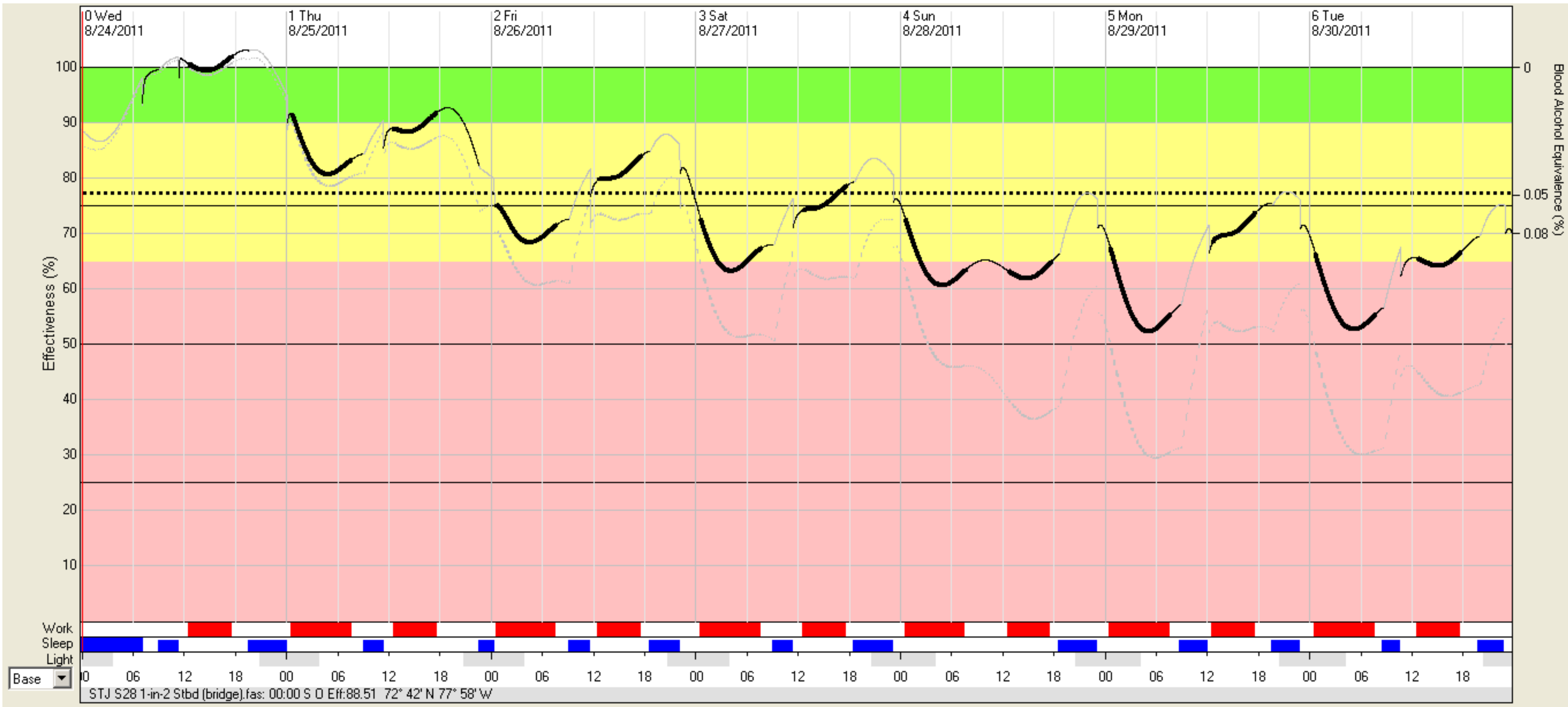
C.7 FAST™ model for Subject 25 (Operations Room, Electronic Warfare Supervisor)



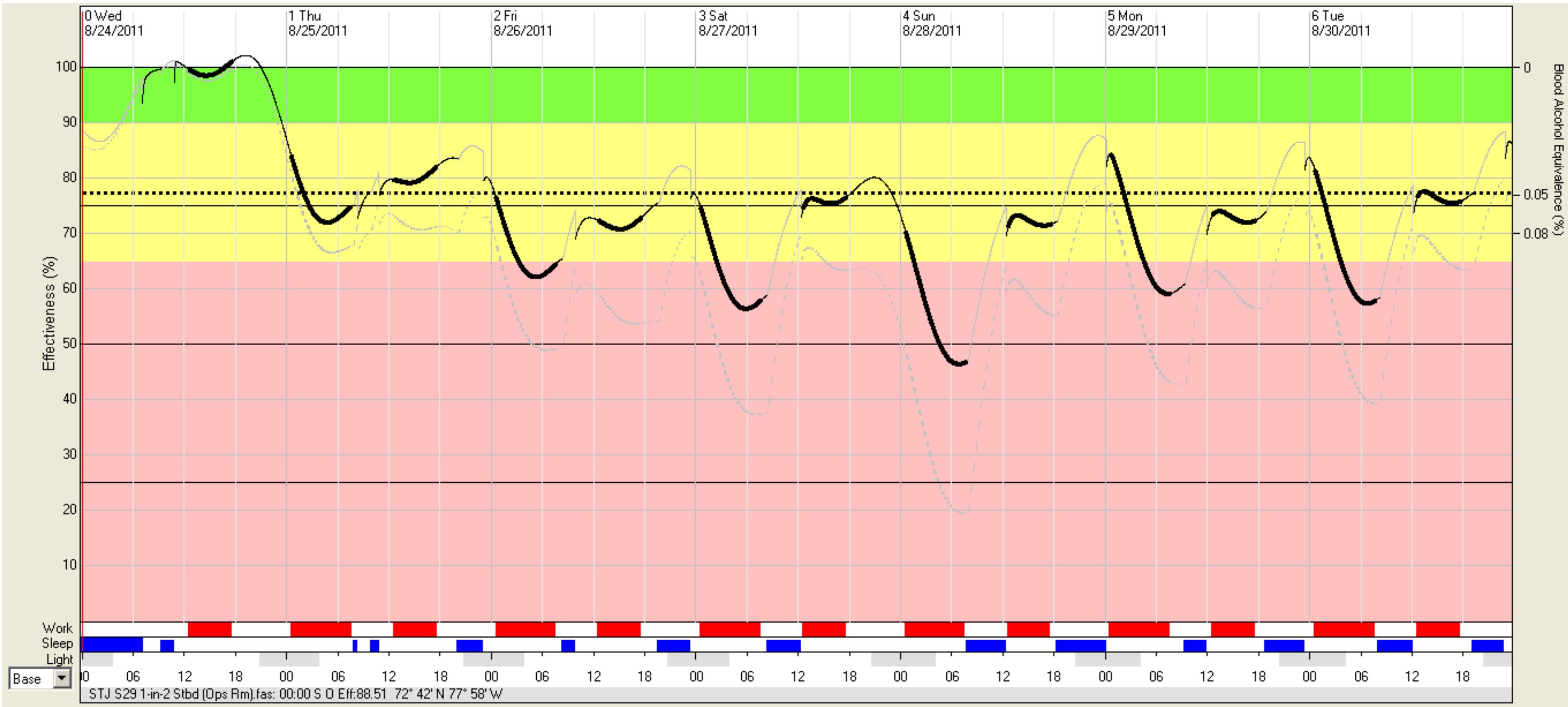
C.8 FAST^{TM} model for Subject 27 (Operations Room, Sonar Operator)



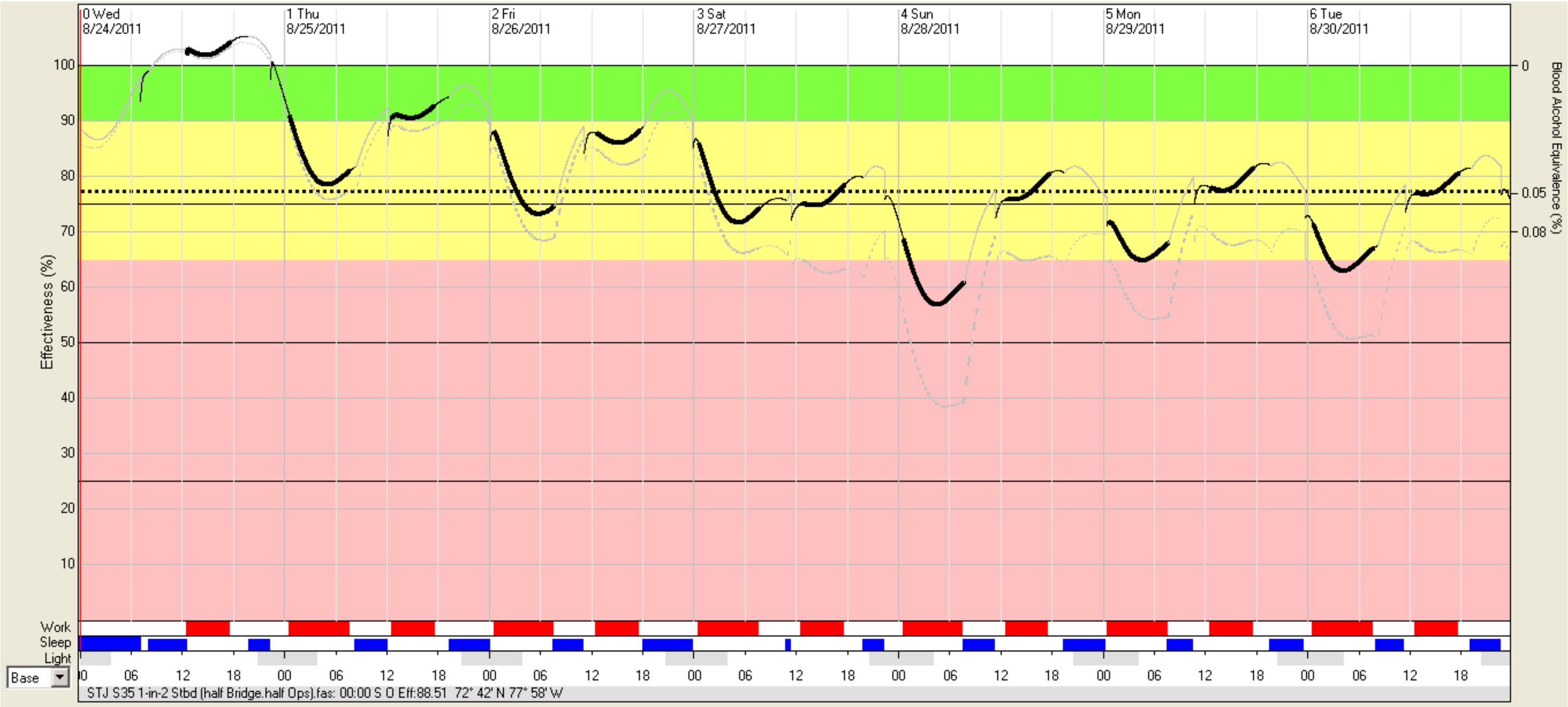
C.9 FAST™ model for Subject 28 (Bridge, Bosun)



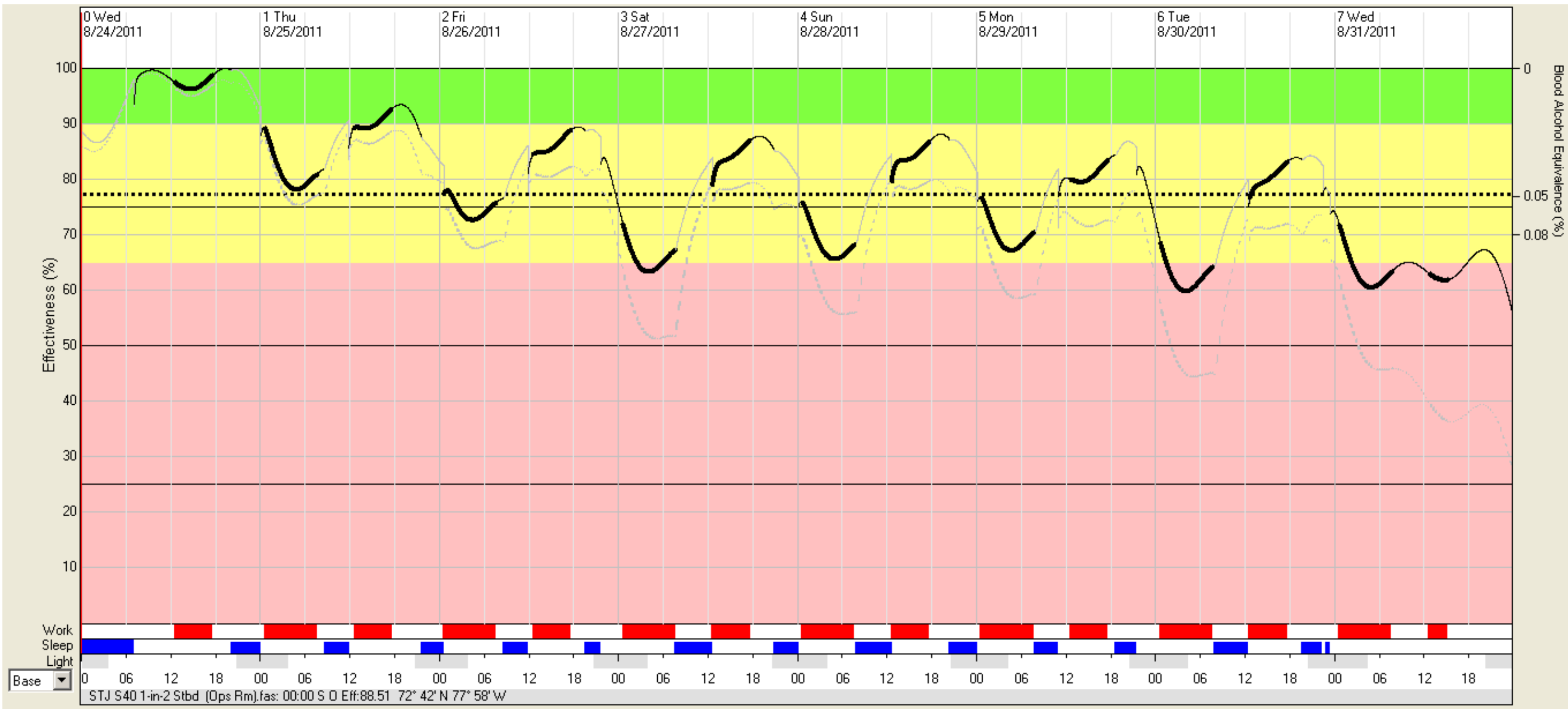
C.10 FAST™ model for Subject 29 (Operations Room, Naval Weapons Technician, Apprentice)



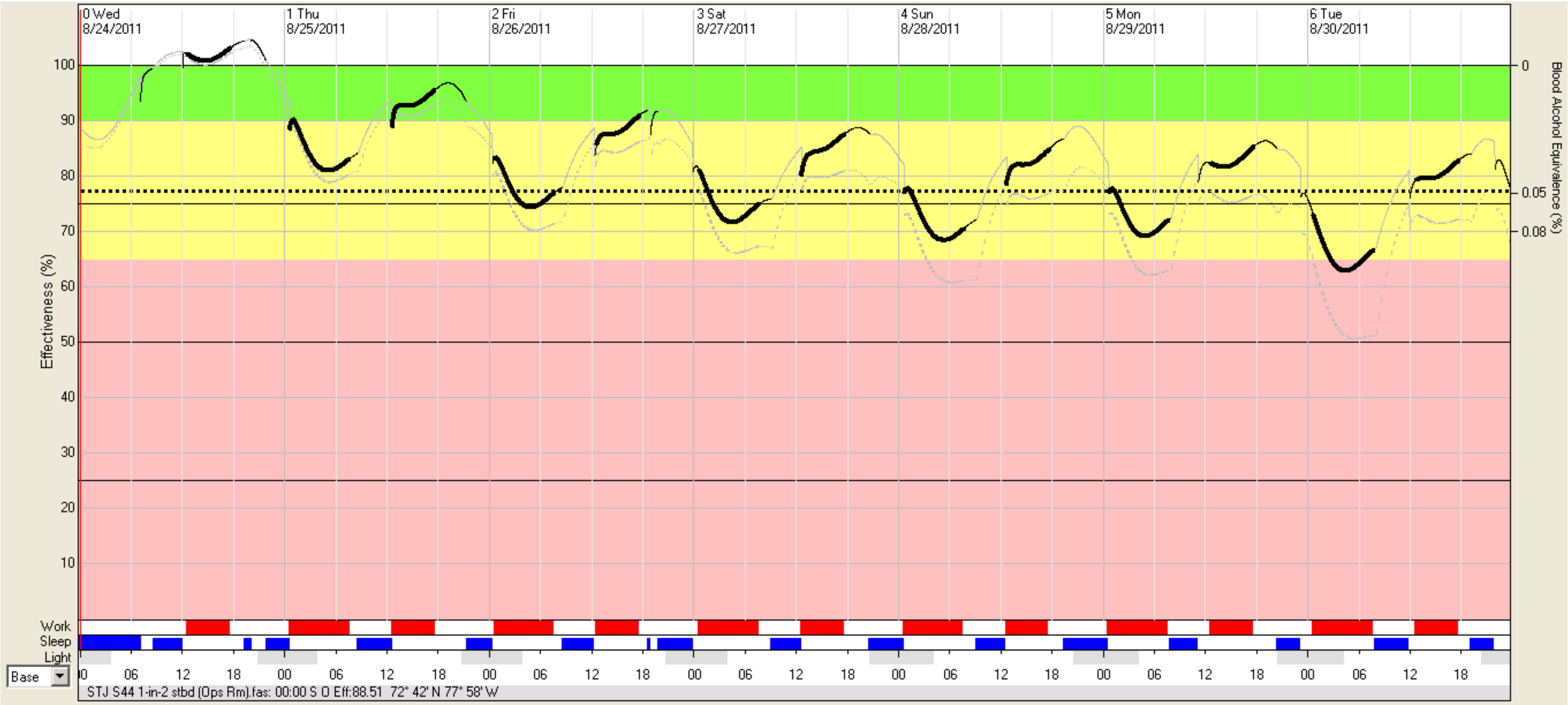
C.11 FAST™ model for Subject 35 (half-time bridge, half-time Operations Room, Bridge Watchkeeper, Trainee)



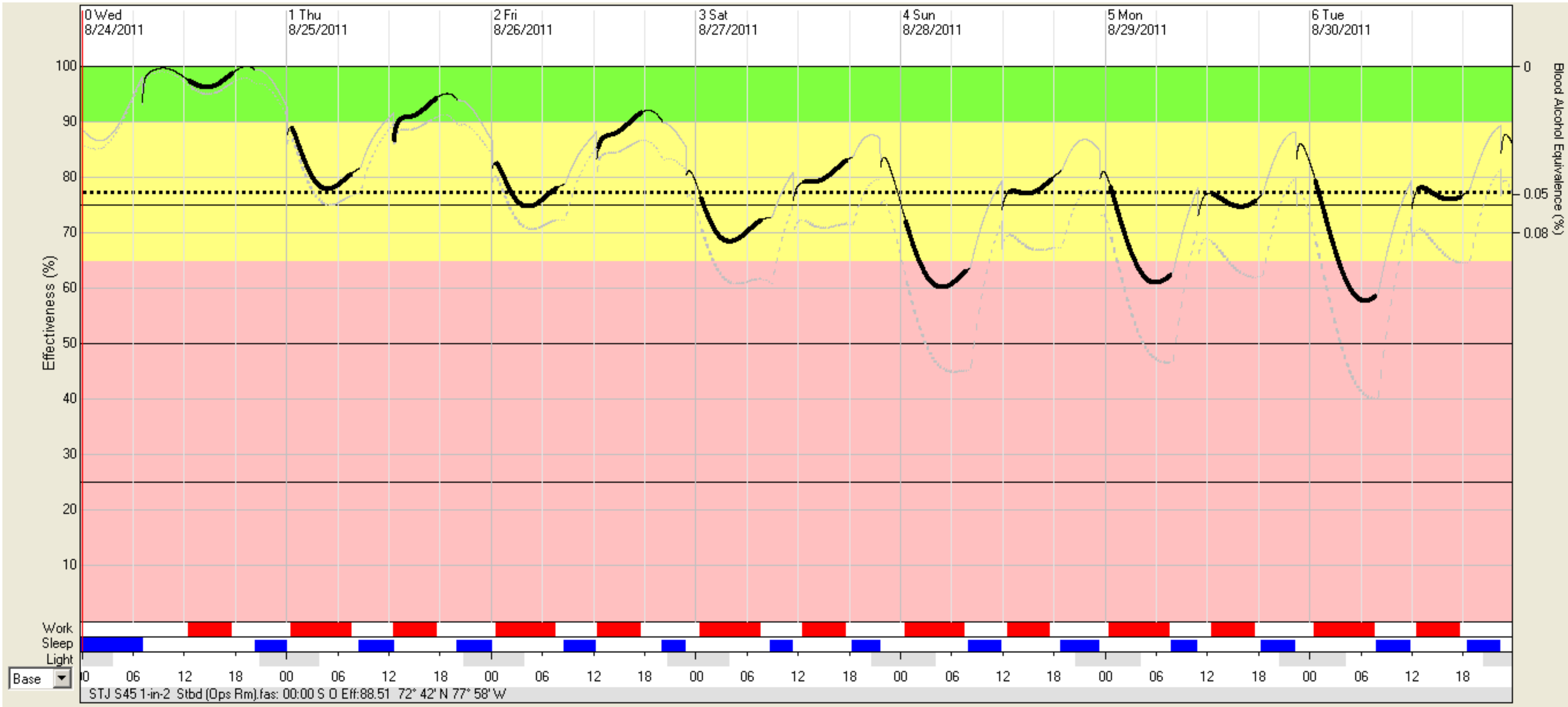
C.12 FAST™ model for Subject 40 (Naval Combat Information Operator & Diver)



C.13 FAST™ model for Subject 44 (Operations Officer, Supervisor)

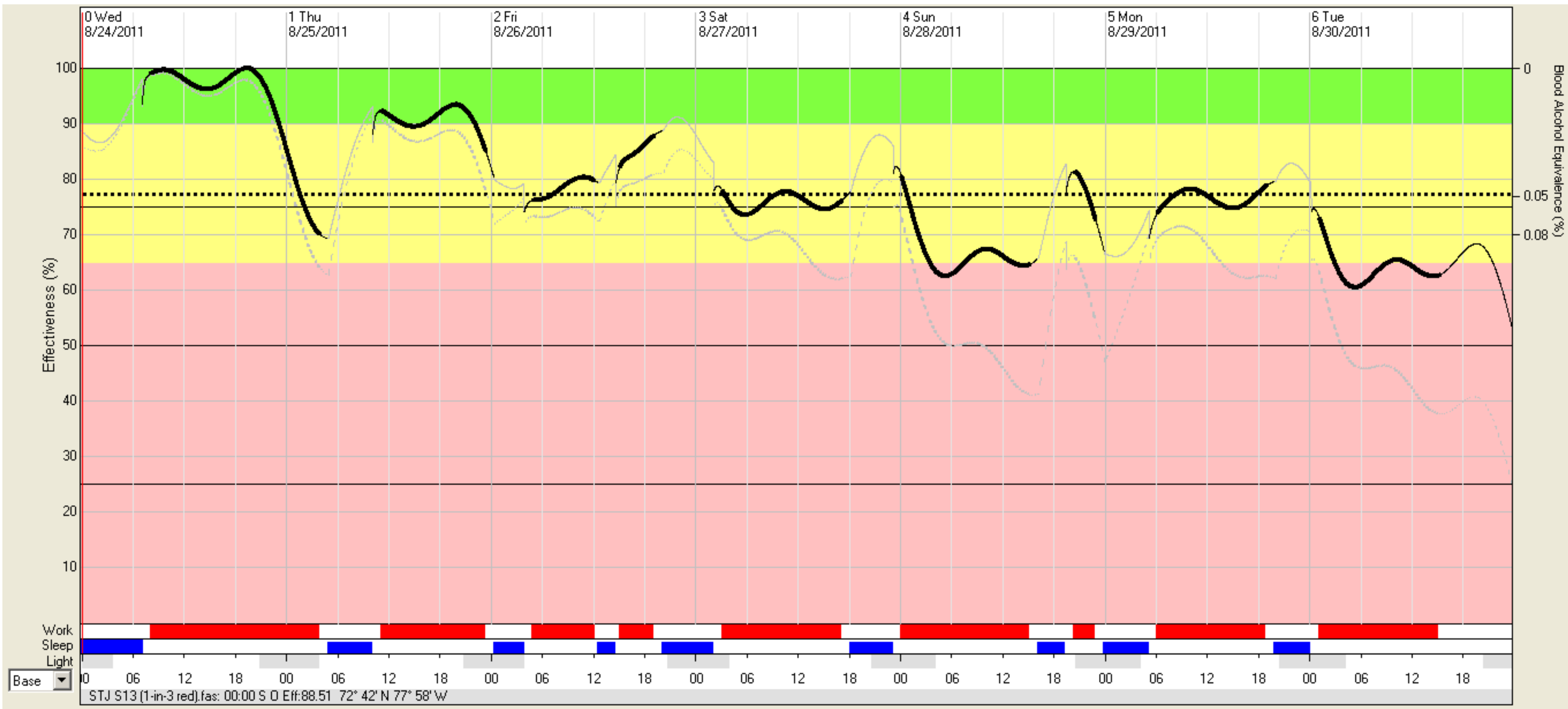


C.14 FAST™ model for Subject 45 (Network, Tactical Maintainer)

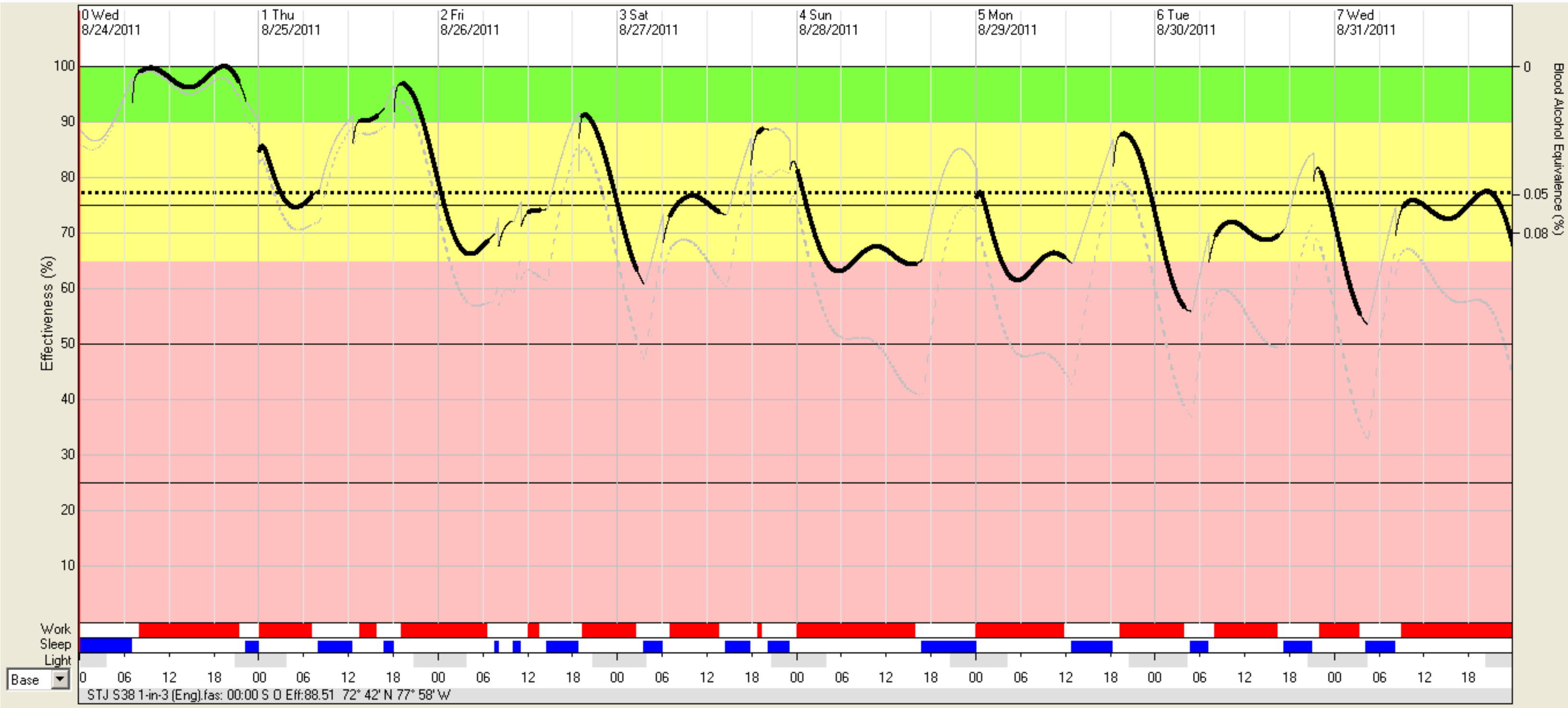


Annex D FAST™ Models for 1-in-3 Engineering Watch Standers

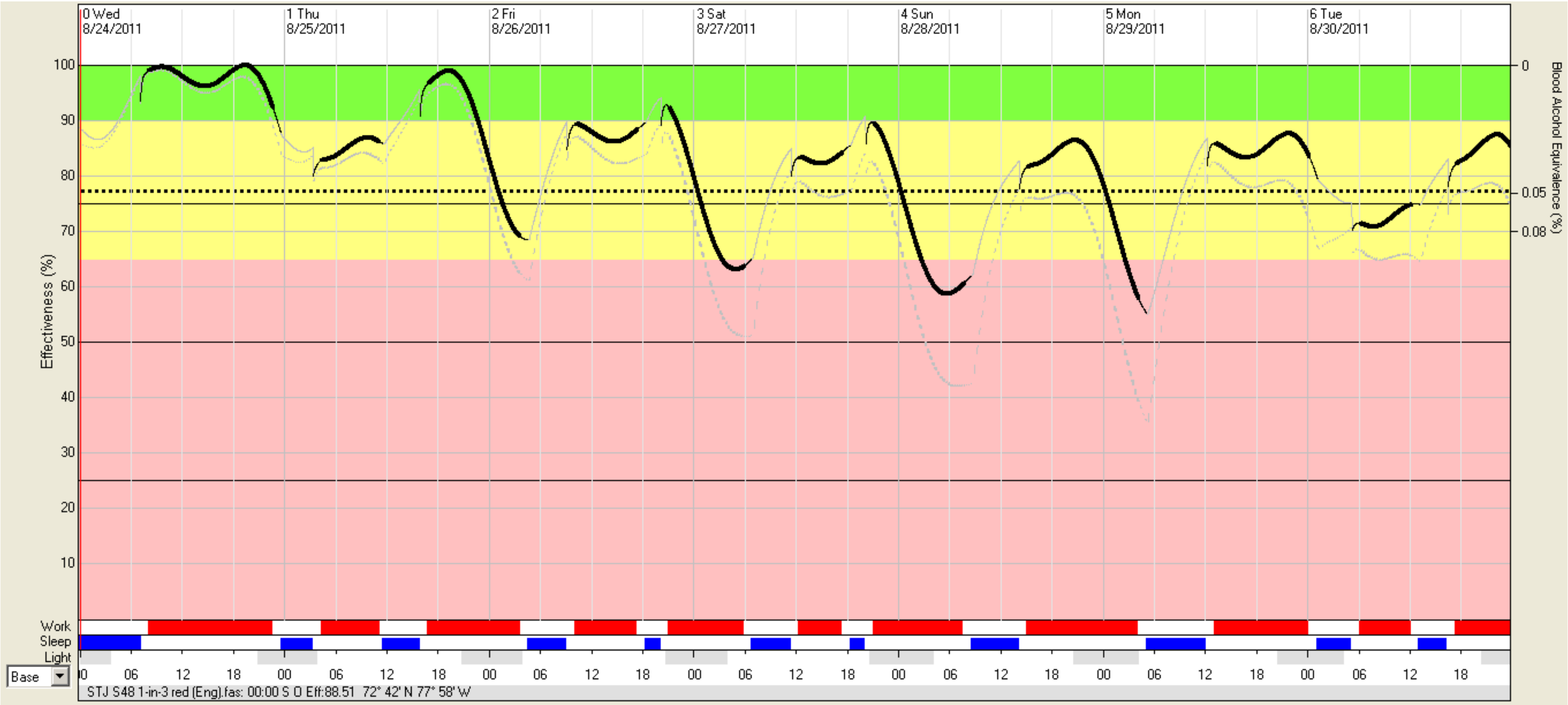
D.1 FAST™ model for Subject 13 (Marine engineering Mechanic (Stoker))



D.2 FAST™ model for Subject 38 (Engineering Roundsman, Engine Room)

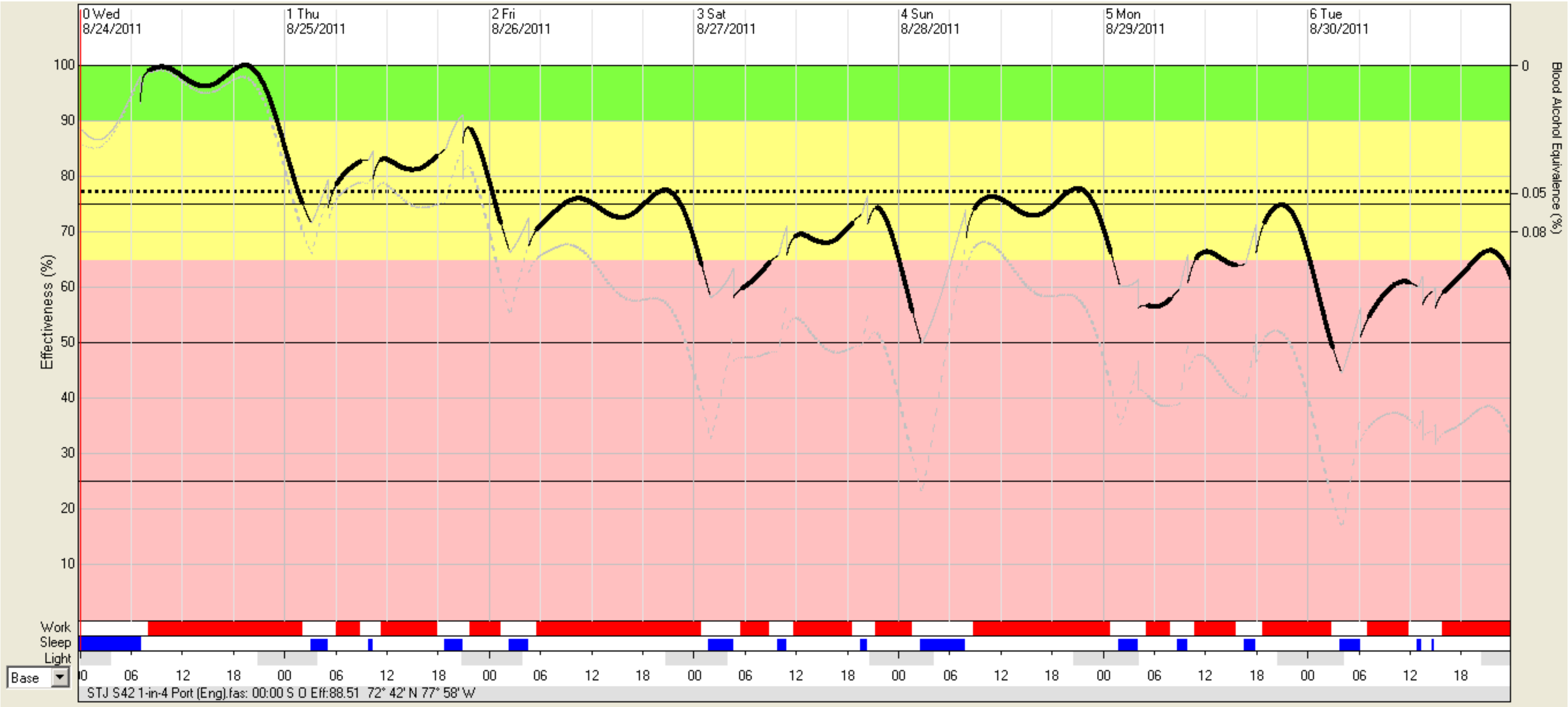


D.3 FAST™ model for Subject 48 (Marine Engineer Technician, Engine Room)

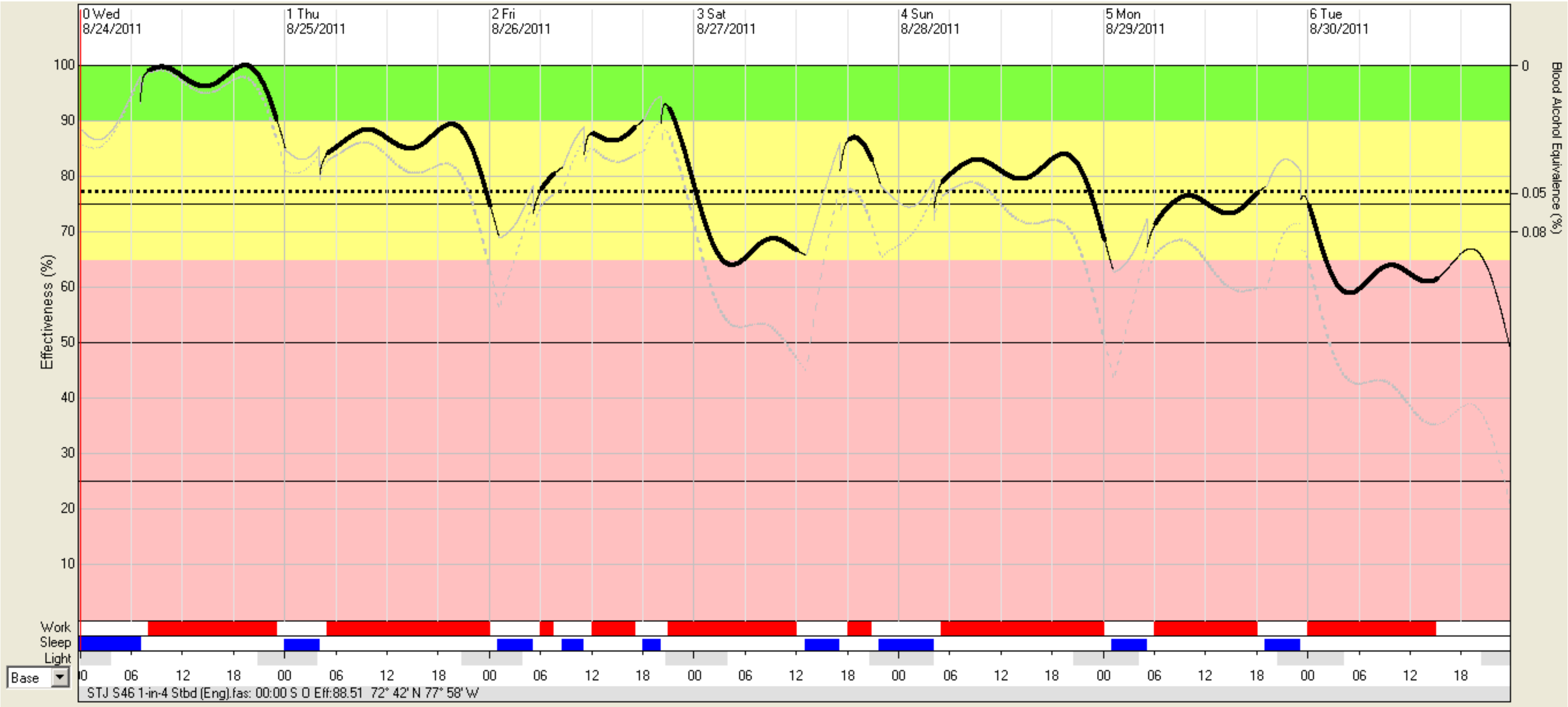


Annex E FAST™ Models for 1-in-4 Engineering Watch Standers

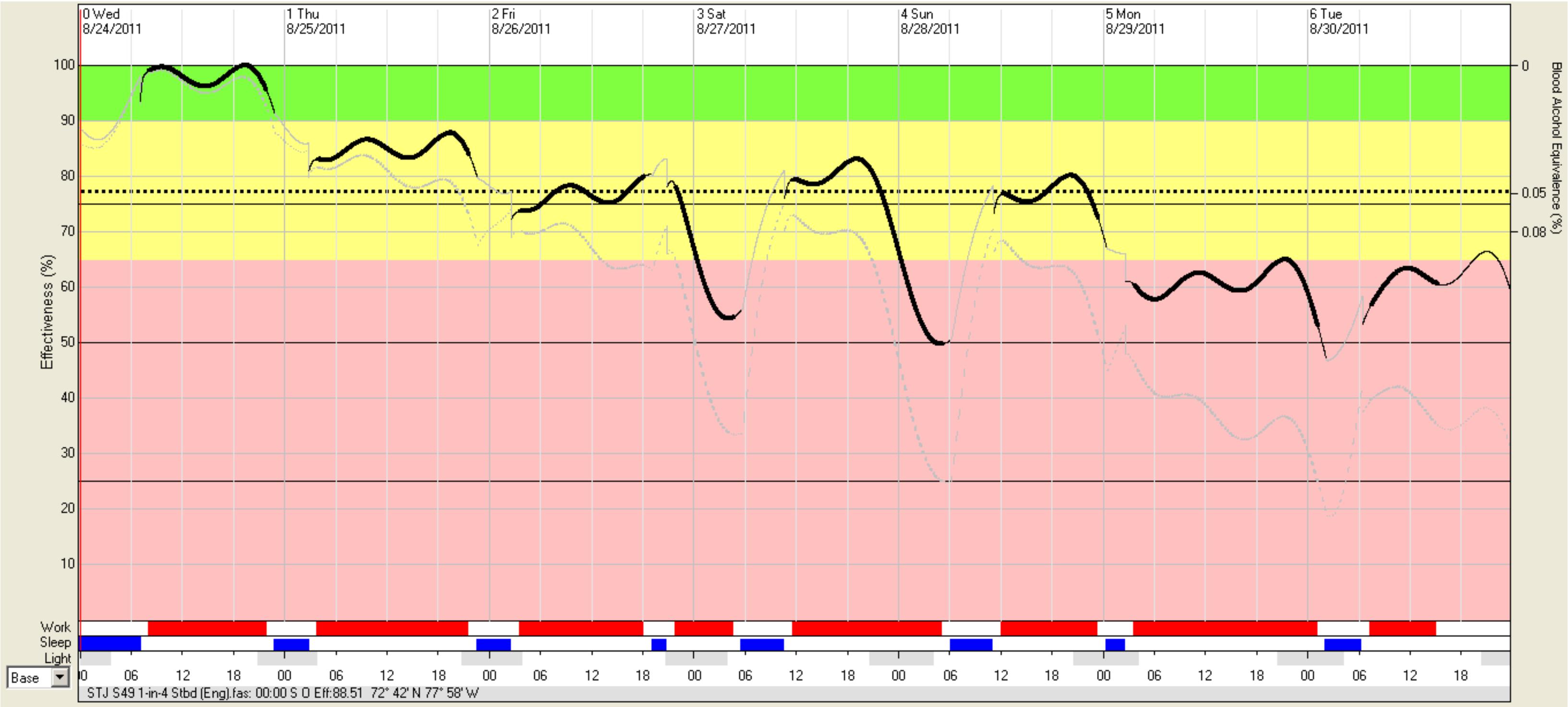
E.1 FAST™ model for Subject 42 (Machinery Control Room/Engine Room, Console Operator)



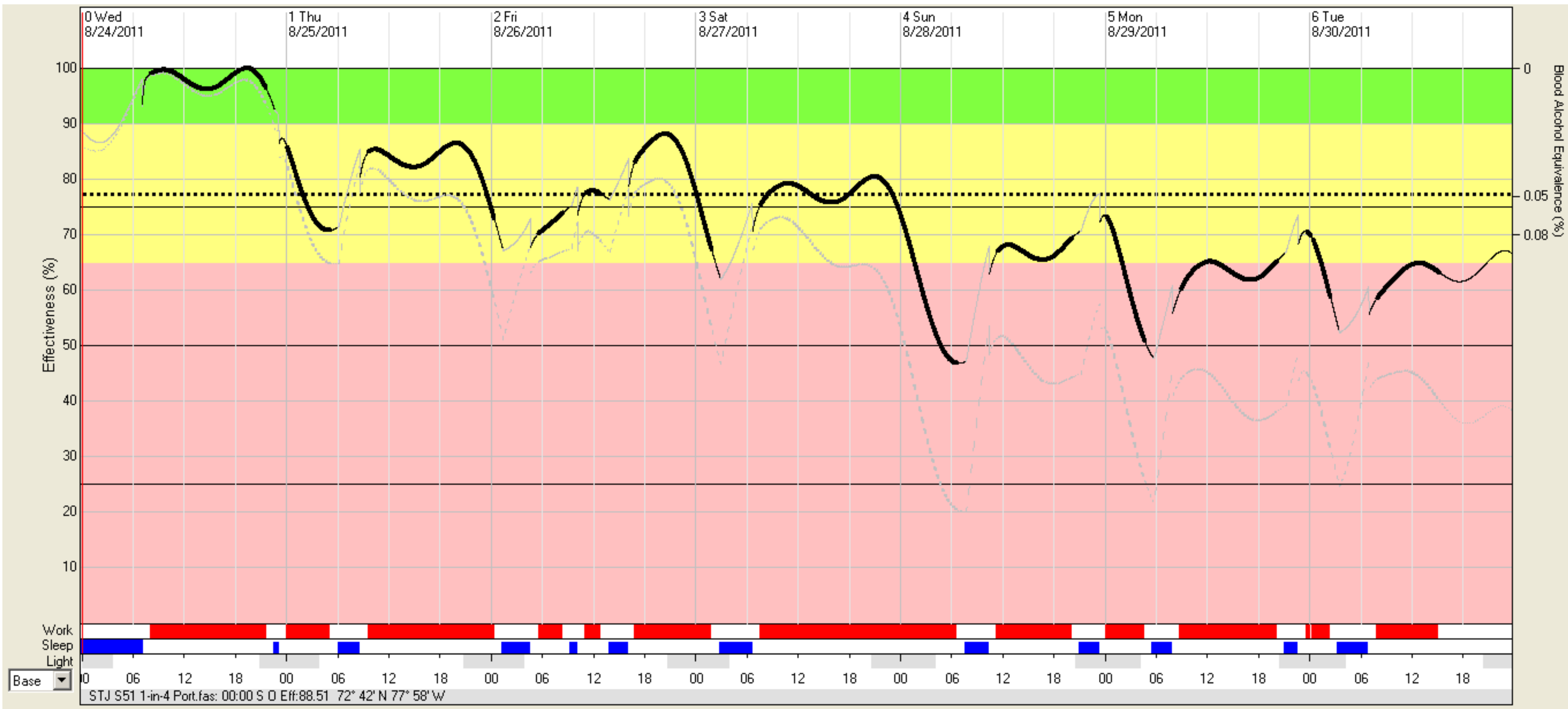
E.2 FAST™ model for Subject 46 (Machinery Control Room/Engine Room, Engineering Officer of the Watch)



E.3 FAST™ model for Subject 49 (Machinery Control Room/Engine Room, Marine Engine Technician (Stoker))



E.4 FAST^{TM} model for Subject 51 (Engine Room, Main Propulsion Petty Officer, Engineering Officer of the Watch)



Annex F Sleep, Activity, Fatigue and Task Effectiveness (SAFTE) Model

F.1 Fatigue Avoidance Scheduling Tool (*FAST*™)

The Sleep, Activity, Fatigue and Task Effectiveness (SAFTE) model integrates quantitative information about (1) circadian rhythms in metabolic rate, (2) cognitive performance recovery rates associated with sleep, and cognitive performance decay rates associated with wakefulness, and (3) cognitive performance effects associated with sleep inertia to produce a 3-process model of human cognitive effectiveness.

The SAFTE model has been under development by Dr. Steven Hursh for more than a decade. Dr. Hursh, formerly a research scientist with the US Army, is employed by SAIC (Science Applications International Corporation) and Johns Hopkins University and is currently under contract to the WFC (Warfighter Fatigue Countermeasures) R&D Group and NTI, Inc. to modify and expand the model.

The general architecture of the SAFTE model is shown in Figure 1. A circadian process influences both cognitive effectiveness and sleep regulation. Sleep regulation is dependent upon hours of sleep, hours of wakefulness, current sleep debt, the circadian process and sleep fragmentation (awakenings during a sleep period). Cognitive effectiveness is dependent upon the current balance of the sleep regulation process, the circadian process, and sleep inertia.

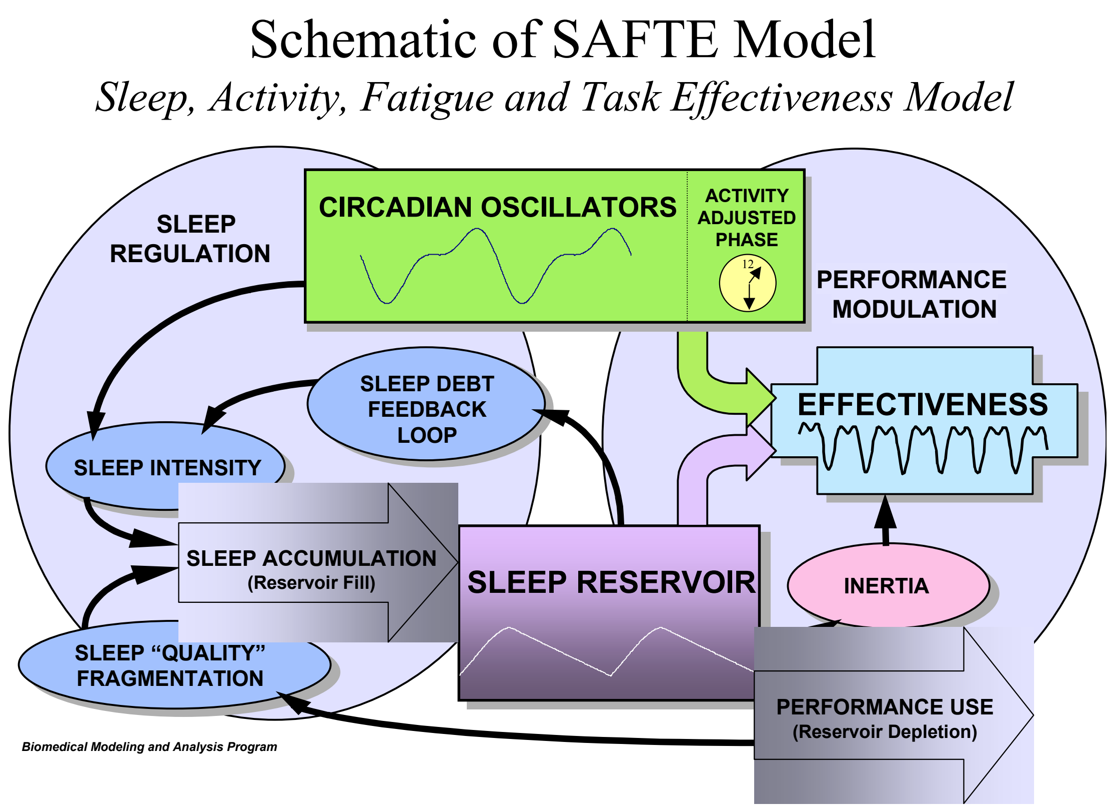


Figure 1. Schematic of SAFTE Model

SAFTE has been validated against group mean data from a Canadian laboratory that were not used in the model's development (Hursh et al., in review). Additional laboratory and field validation studies are underway and the model has begun the USAF Verification, Validation and Accreditation (VV&A) process.

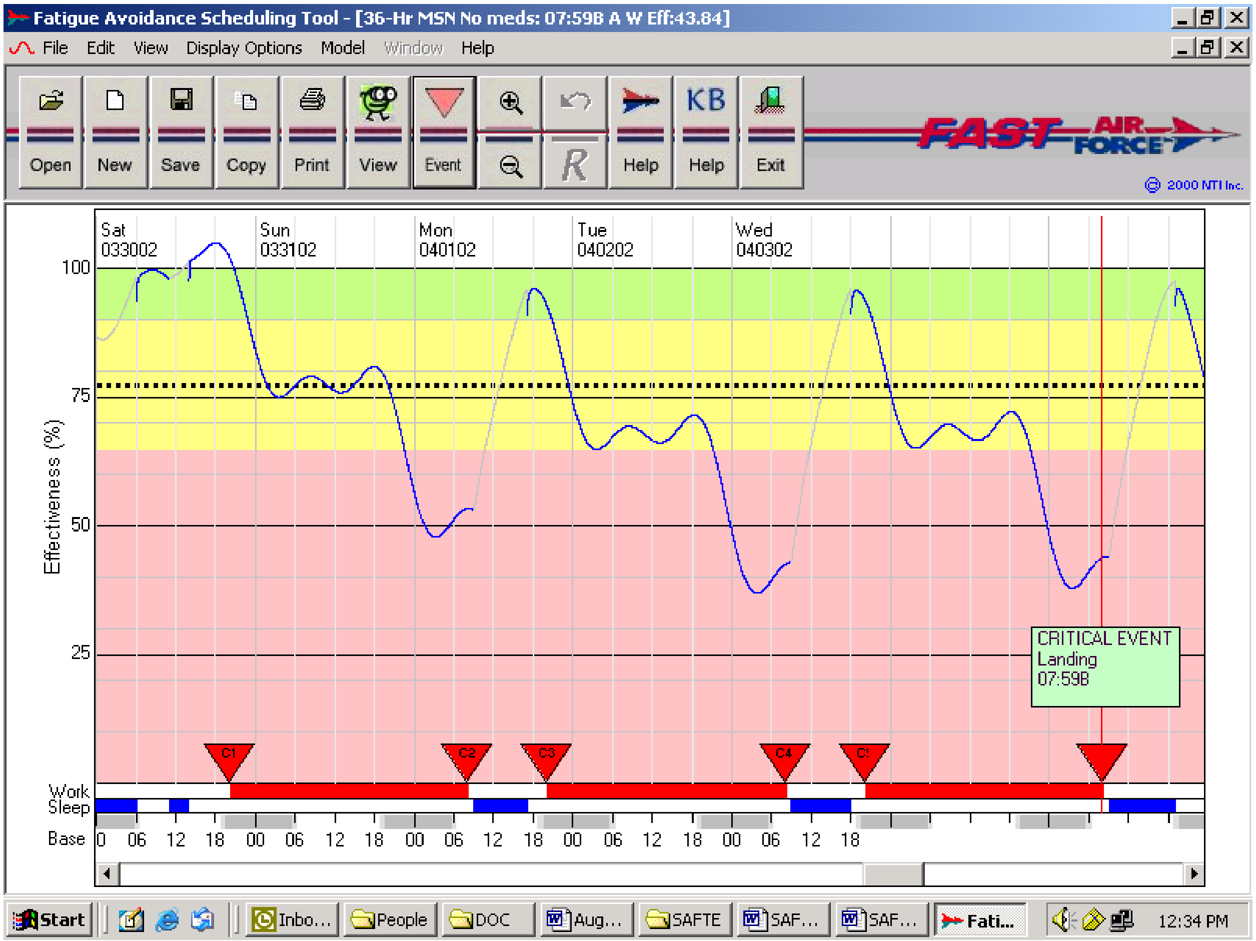
The model does not incorporate the effects of pharmacological alertness aids; chronic fatigue (motivational exhaustion); chronic fatigue syndrome; fatiguing physiological factors such as exercise, hypoxia or acceleration; sleep disorders; or the fatiguing effects of infection.

The SAFTE Model has a number of essential features that distinguish it from other attempts to model sleep and fatigue (Table D-1). Together, these features of the model allow it to make very accurate predictions of performance under a variety of work schedules and levels of sleep deprivation.

Table D-1. SAFTE model essential features.

KEY FEATURES	ADVANTAGES
Model is homeostatic. Gradual decreases in sleep debt decrease sleep intensity. Progressive increases in sleep debt produced by extended periods of less than optimal levels of sleep lead to increased sleep intensity.	Predicts the normal decline in sleep intensity during the sleep period. Predicts the normal equilibrium of performance under less than optimal schedules of sleep.
Model delays sleep accumulation at the start of each sleep period.	Predicts the detrimental effects of sleep fragmentation and multiple interruptions in sleep.
Model incorporates a multi-oscillator circadian process.	Predicts the asymmetrical cycle of performance around the clock.
Circadian process and Sleep-Wake Cycle are additive to predict variations in performance.	Predicts the mid-afternoon dip in performance, as well as the more predominant nadir in performance that occurs in the early morning.
Model modulates the intensity of sleep according to the time of day.	Predicts circadian variations in sleep quality. Predicts limits on performance under schedules that arrange daytime sleep.
Model includes a factor to account for the initial lag in performance upon awakening.	Predicts sleep inertia that is proportional to sleep debt.
Model incorporates adjustment to new time zones or shift schedules	Predicts temporary “jet-lag” effects and adjustment to shift work

The Fatigue Avoidance Scheduling Tool (*FAST*™) is based upon the SAFTE model. *FAST*™, developed by NTI, Inc. as an AF SBIR (Air Force, Small Business Innovative Research) product, is a Windows® program that allows planners and schedulers to estimate the average effects of various schedules on human performance. It allows work and sleep data entry in graphic and text formats. A work schedule comprised of three 36-hr missions each separated by 12 hours is shown as red bands on the time line across the bottom of the graphic presentation format in Figure 2. Average performance effectiveness for work periods may be extracted and printed as shown in the table below the figure.



AWAKE			WORK		
Start Day - Hr	Duration (Minutes)	Mean Effectiveness	Start Day - Hr	Duration (Minutes)	Mean Effectiveness
0 - 06:00	300	98.97	0 - 20:00	1079	81.14
0 - 14:00	2580	76.42	1 - 14:00	1080	63.97
2 - 17:00	2400	64.78	2 - 20:00	1079	71.23
4 - 18:00	2340	64.58	3 - 14:00	1080	54.51
6 - 19:00	1741	72.23	4 - 20:00	1079	72.00
			5 - 14:00	1080	54.92

Figure 2: Sample FAST[tm] display. The triangles represent waypoint changes that control the amount of light available at awakening and during various phases of the circadian rhythm. The table shows the mission split into two work intervals, first half and second half.

Sleep periods are shown as blue bands across the time line, below the red bands.

The vertical axis of the diagram represents composite human performance on a number of associated cognitive tasks. The axis is scaled from zero to 100%. The oscillating line in the diagram represents expected group average performance on these tasks as determined by time of

day, biological rhythms, time spent awake, and amount of sleep. We would expect the predicted performance of half of the people in a group to fall below this line.

The green area on the chart ends at the time for normal sleep, ~90% effectiveness.

The yellow indicates caution.

The area from the dotted line to the red area represents performance level during the nadir and during a 2nd day without sleep.

The red area represents performance effectiveness after 2 days and a night of sleep deprivation.

The expected level of performance effectiveness is based upon the detailed analysis of data from participants engaged in the performance of cognitive tasks during several sleep deprivation studies conducted by the Army, Air Force and Canadian researchers. The algorithm that creates the predictions has been under development for two decades and represents the most advanced information available at this time.

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List of symbols/abbreviations/acronyms/initialisms

ANOVA	Analysis of Variance
BAC	Blood Alcohol Content
CCR	Communications Control Room
DND	Department of National Defence
DRDC	Defence Research & Development Canada
DRDKIM	Director Research and Development Knowledge and Information Management
EOOW	Engineering Officer of the Watch
$FAST^{TM}$	Fatigue Avoidance Scheduling Tool
LSD	Least Significant Difference
MCR	Machinery Control Room
NCIOP	Naval Combat Information Operator
NESOP	Naval Electronic Sensor Operator
NWT	Naval Weapons Technician
R&D	Research and Development
RAN	Royal Australian Navy
RCN	Royal Canadian Navy
RNLN	Royal NetherLands Navy
SOAP	Special Operations Assessment Profile
STOKER	Marine Engineering Technician/Mechanic
USN	United States navy
VAS	Visual Analogue Scale
WASO	Wake After Sleep Onset

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An assessment of some watch schedule variants used in Cdn Patrol Frigates: OP Nanook 2011

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Background. Previous research conducted by DRDC Toronto to evaluate watch schedule variants used on RCN submarines indicated very significant and deleterious effects of the watch system on modeled cognitive effectiveness of RCN submariners. Subsequently, DRDC Toronto hosted an International Submarine Watch Schedule Symposium which led to a new RCN submarine watch schedule which improved modeled performance by about 30%. The RCN surface fleet is aware of this work and supported a request to conduct an evaluation of the surface fleet watch schedule. We evaluated the watch schedules used aboard HMCS St John's at the end of Op Nanook 2011, over the 8 days that STJ transitioned from the high Arctic to Halifax. **Methods.** The ages of the forty-five sailors who participated in this at-sea trial ranged from 21 to 48 years, with a mean age and standard deviation of 32.9 ± 7.7 years. Ten of these sailors were non-watch-standers, 14 sailors were from the 1-in-2 Port (Front) watch, 14 sailors were from the 1-in-2 Starboard (Back) watch, three sailors were from the 1-in-3 Engineering watch, and four sailors were from the 1-in-4 Engineering watch. All subjects wore wrist activity monitors (actigraphs) to measure their daily sleep patterns quantitatively. The actigraphically-measured sleep and daily work hours were the two data sets that were inputted to the FAST™ (Fatigue Avoidance Scheduling Tool) software to generate modeled cognitive effectiveness for each subject. All subjects maintained a daily activity, sleep and mood log. **Results.** Modeled cognitive effectiveness showed worrisome levels of performance equivalent to intoxicated levels of blood alcohol (BAC 0.05% and 0.08%) and well beyond those levels for all watch system variants. The main effect of 'groups' for 'difficulty falling asleep' was significant with post hoc tests showing that the 1-in-2 Port (Front) watch had less difficulty getting to sleep relative to the non-watch standers. With respect to the Visual Analogue Scale data, the non-watch-standers reported being in a 'happier' mood than either of the 1-in-2 Port (Front) and Starboard (Back) watch. Collapsed over the non-watch-standers, 1-in-2 Port (Front) watch, and 1-in-2 Starboard (Back) watch syndicates, 6 SOAP parameters (difficulty concentrating, level of depression, level of irritability, level of fatigue, work frustration and physical discomfort) deteriorated during the trial relative to the pre-trial baseline. **Conclusions.** The current surface fleet watch schedule is sub-optimal in that it results in worrisome levels of cognitive effectiveness in many of our sailors. **Recommendations.** An alternative watch schedule which is more sparing of submariner cognitive effectiveness should be developed and implemented. Please see the details of an alternative watch system in the body of this report under 'recommendations'.

Contexte. Des recherches antérieures réalisées par RDDC Toronto pour évaluer les variantes d'horaire de garde utilisées à bord des sous-marins de la MRC montrent des incidences importantes et néfastes du système de quart sur l'efficacité cognitive des sous-mariniers. Subséquemment, RDDC Toronto a organisé un symposium international sur les horaires de garde à bord des sous-marins qui a permis de réaliser un nouvel horaire de garde à bord des sous-marins de la MRC, améliorant d'environ 30 p. cent le rendement modélisé. Les membres de la flotte de surface de la MRC connaissent ces travaux et ont demandé qu'une évaluation de l'horaire de garde de la flotte de surface soit réalisée. Nous avons évalué les horaires de garde utilisés à bord du NCSM St *John's* à la fin de l'opération Nanook 2011, pendant les huit jours de la traversée du *St John's* de l'Extrême-Arctique à Halifax. **Méthodologie.** Les quarante-cinq marins qui ont participé à cette expérience en mer étaient âgées de 21 à 48 ans, avec une moyenne d'âge de 32,9 ans et un écart type de ± 7,7 ans. Dix de ces marins étaient affectés à des postes autres que des poste de garde, quatorze étaient affectés comme vigies de quart avant, à raison d'un tour de garde sur deux, quatorze comme vigies de quart arrière, à raison d'un tour de

garde sur deux, trois comme mécaniciens chefs de quart, à raison d'un tour de garde sur trois et quatre comme mécaniciens chefs de quart, à raison d'un tour de garde sur quatre. Chacun des participants portait un bracelet moniteur (actigraphe) de ses activités, afin de mesurer quantitativement sa structure de sommeil. Les heures de travail quotidien et de sommeil mesurées par actigraphe sont les deux ensembles de données enregistrés dans le logiciel FASTTM (*Fatigue Avoidance Scheduling Tool*) pour établir l'efficacité cognitive de chaque participant. Tous les participants ont tenu, quotidiennement, un registre sur leurs activités, leur sommeil et leur humeur. **Résultats.** L'efficacité cognitive a montré des niveaux de rendement inquiétants, équivalents à un rendement en état d'ébriété (à un taux d'alcoolémie se situant entre 0,05 % et 0,08 %) et bien au-delà des niveaux de toutes les variantes d'un système de garde. Le principal effet des « groupes » à l'égard de la « difficulté à s'endormir » s'est avéré important dans les essais ultérieurs montrant que les vigies de quart avant, à raison d'un tour sur deux, avaient moins de difficulté à s'endormir que les marins affectés à des postes autres que des poste de garde. En ce qui concerne les données de l'échelle visuelle analogue, les marins affectés à des postes autres que des poste de garde se sont avérés être de meilleure humeur que les vigies de quart avant et les vigies de quart arrière, à raison d'un tour de garde sur deux. Tant chez les marins affectés à des postes autres que des poste de garde, que chez les vigies de quart avant et les vigies de quart arrière, à raison d'un tour de garde sur deux, six paramètres du profil d'évaluation des opérations spéciales (difficulté de concentration, niveau de dépression, niveau d'irritabilité, niveau de fatigue, frustration au travail et inconfort physique) se sont détériorés au cours de l'essai. **Conclusions.** L'horaire de garde actuel de la flotte de surface est sous-optimal du fait qu'il entraîne une réduction inquiétante du niveau d'efficacité cognitive de certains de nos marins. **Recommandations.** Un nouvel horaire de garde, moins éprouvant pour l'efficacité cognitive des sous-mariniers, devrait être élaboré et mis en œuvre. Veuillez voir les détails d'un nouvel horaire de garde dans le corps du présent rapport sous « Recommandations ».

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naval watch schedule; shiftlag; fatigue; cognitive effectiveness

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